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LANGUAGES FOR SCIENCE.

BY

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As everyone knows, the scientific world had at one time a universal language—Latin. A scientific publication from any country could be read without translation by any scientist, no matter what his nationality. Direct communication, verbally or by letter, was possible for all scientists. For five centuries this internationality existed, to be gradually replaced by a narrow nationalism. Since 1850 practically no scientific work has been published in Latin. In fact, the twentieth century has seen a growing provincialism in the face of a glorious development in communication and transportation. It has become the custom of even the smallest countries to expect their scientists to publish in the national tongue, though such a step reduces the usefulness of the publication.

As a result, the scientist of today is isolated from his fellows in other lands. Even though he has mastered English, French, and German, he may be unable to understand a scientist from South America, Italy, Poland, or Russia. An important research, published in Dutch or Swedish or Japanese, may be entirely overlooked, with resulting loss to the whole scientific world. Language difficulties intrude also in every attempt at international standardization and in all international scientific congresses.

The revolt against Latin as the language of science was part of the humanistic revolt against class privilege (1).[3] As such it was commend-

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[3] The boldface numbers in parentheses refer to the references appended to this paper.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

TABLE I.—*Languages Used for Scientific Publications.*

Author		Important Publication	Date	Language
Italy:				
Leonardo of Pisa	1175–1250	Liber abaci	1202	Latin
Galileo Galilei	1564–1642	Saggiatore	1623	Italian
Francesco Grimaldi	1618–1663	Physico-mathesis de lumine, coloribus, et iride	1665	Latin
G. Saccheri	1667–1733	Euclides ab omni naevo vindicatus	1733	Latin
Luigi Galvani	1737–1798	De viribus electricitatis in motu musculari commentarius	1791	Latin
L. Cremona	1830–1903	Various papers on geometry	—	Italian
France:				
Franciscus Vieta	1540–1603	In artem analyticam isogoge	1591	Latin
		De numerosa potestatum resolutione	1600	Latin
		De aequationum recognitione et emendatione	1615	Latin
Albert Girard	1595–1632	Invention nouvelle en l'algébra	1629	French
Girard Desargues	1593–1662	Brouillon project d'une atteinte aux événemens des rencontres d'un cône avec un plan	1639	French
Réné Descartes	1596–1650	Discours de la méthode	1637	French
P. de la Hire	1640–1718	Sectiones conicae	1685	Latin
G.F.A. l'Hôpital	1661–1704	Analyse des infiniment petits	1696	French
A. de Moivre	1667–1754	Miscellanea analytica	1730	Latin
Pierre Bouguer	1698–1758	Traité d'optique sur la gradation de la lumière	1760	French
A. C. Clairaut	1713–1765	Théorie de la figure de la terre	1743	French
J. d'Alembert	1717–1783	Traité de dynamique	1743	French
C. A. Coulomb	1736–1806	Various papers	—	French
J. L. Lagrange	1736–1813	Mécanique analytique	1788	French
Gaspard Monge	1746–1818	Géometrie descriptive	1798	French
P. S. Laplace	1749–1827	Mécanique céleste	1799–1825	French
A. L. Cauchy	1789–1857	Cours d'analyse	1821	French
J. B. J. Fourier	1758–1830	La théorie analytique de la chaleur	1822	French
Great Britain:				
William Gilbert	1540–1603	De magnete	1600	Latin
John Napier	1550–1617	Mirifici logarithmorum canonis descriptio	1614	Latin
Thomas Harriot	1560–1621	Artis analyticae praxis	1631	Latin
Francis Bacon	1561–1626	Novum organum	1620	Latin

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TABLE I.—*Continued.*

Author		Important Publication	Date	Language
John Wallis	1616–1703	Arithmetica infinitorum	1655	Latin
Isaac Barrow	1630–1677	Various papers	—	Latin
Robert Hooke	1635–1703	Micrographia	1665	Latin
Roy. Soc. of London	1622–	Phil. Trans.	1665–	English
Isaac Newton	1642–1727	Principia	1687	Latin
Brook Taylor	1685–1731	Methodus incrementorum directa et inversa	1715	Latin
Colin Maclaurin	1698–1746	Treatise on fluxions	1742	English
Thomas Simpson	1710–1761	New treatise on fluxions	1737	English
Robert Smith	—	Compleat system of optiks	1738	English
W. R. Hamilton	1805–1865	Elements of quaternions	1866	English
Arthur Cayley	1821–1895	Various papers	—	English
Germany:				
Johann Kepler	1571–1630	Mysterium cosmographicum	1596	Latin
G. W. Leibniz	1646–1716	De arta combinatoria	1666	Latin
Berlin Academy	1700–		1700–	Latin
Leonhard Euler	1707–1783	700 Scientific papers	—	Latin
J. H. Lambert	1728–1777	Photometria	1760	Latin
C. F. Gauss	1777–1855	Papers to about 1830	—	Latin
		Later papers	—	German
A. F. Möbius	1790–1868	Papers	—	German
C. G. J. Jacobi	1804–1851	Papers	—	Latin
Other Countries:				
Nicolaus Copernicus (Poland)	1473–1543	De revolutionibus orbium coelestium	1543	Latin
Tycho Brahe (Denmark)	1546–1601	De nova stella	1573	Latin
Christian Huygens (Netherlands)	1629–1695	Papers	—	Latin Dutch French
Johann Bernoulli (Switzerland)	1667–1748	Lectiones mathematicae de methodo integralium	1742	Latin
Daniel Bernoulli	1700–1782	Hydrodynamica	1738	Latin
Wolfgang Bolyai (Hungary)	1775–1856	Papers	—	Latin
P. L. Tchebychef (Russia)	1821–1894	Papers	—	French

able. But the use of the national languages for scientific purposes merely replaces a previous class distinction by a much worse national distinction. The present state of affairs shows very clearly that the scientific world has been moving in the wrong direction linguistically for the past century. Something should be done. In the following pages, an attempt is made to outline the problem in an unbiased manner and to study possible solutions.

LATIN.

In the middle ages, Latin was the language of culture throughout Europe. Thus when educated people began to write about scientific subjects, they wrote in Latin (2). Leonardo (Italy, 1175–1250) in writing his treatise on algebra in 1202 used Latin, as did Roger Bacon (England, 1214–1292) in advocating the experimental method.

Latin was employed in nearly all scientific publications up to 1630, and in some cases it was used even after 1830. Since the study of Latin was an important part of the schooling of every educated person, there was no trouble with noninternationality in scientific publications. That the use of a single language for science was an advantage can hardly be doubted by anyone who examines a part of the voluminous scientific correspondence that was carried on throughout Europe (3). It was in Latin. While the merchants of Amsterdam, London, Venice, and Lisbon might tear their hair over language difficulties, the scientists were serenely free from such impediments. But by the twentieth century this freedom had disappeared. Now, even in peace times, it seldom occurs to a scientist to compare notes with anyone outside his own country.

Table I lists some of the great physicists and mathematicians. In most cases, an important book of each is noted and its language is stated. In this way, the table gives an idea of when the transition occurred from Latin to the national language. There is, of course, no sudden break. The language used in a scientific work depended to some extent on the class of readers to whom it was addressed and the country in which it was published. For example, William Gilbert, court physician to Queen Elizabeth, wrote his celebrated treatise on magnetism (1600) in Latin; but Robert Norman, writing a practical description of the compass ("The newe attractive," 1581), used English.

Also, the transition did not occur simultaneously in the different countries of Europe. For example, Jacobi (Germany, 1804–1851) wrote most of his important mathematical papers, throughout his life, in Latin. But the great French mathematicians were employing French exclusively, two centuries before Jacobi. Desargues (1593–1662), Descartes (1596–1650), de Moivre (1667–1754), Lagrange (1736–1813), Laplace (1749–1827), Cauchy (1789–1857), all used French. Another

example is the famous treatise on photometry by Lambert (Germany) published in Latin in 1760, and the equally important work on the same subject by Bouguer (France) which was published in the same year but in the author's native language.

One concludes from Table I, then, that:

1. Scientists in all European countries employed Latin before about 1630,
2. Practically no Latin was used in science after 1850,
3. The transition from Latin to the national speech occurred at different times in different countries. It took place first in France and last in Germany. Table II indicates the approximate dates.

TABLE II.—*Approximate Date of Transition from Latin to a National Language for the Publication of Scientific Works.*

Country	Date
France	1630
England	1700
Germany	1830

If an international language is desirable in science, why was Latin abandoned after it had been used for several centuries? The change was caused by the wave of humanism that swept Europe (1). The special privileges of the aristocracy were to be abolished and the common man was to be given a "new deal." This idea had been felt strongly by that radical, Galileo (1564–1642), who wrote his scientific works in the language of the people. The change in Italy, however, did not in general occur until much later, largely because of the influence of the Church.

The feeling grew that the results of scientific research should not be the property of the learned but should be written in a language that could be understood by the common man. A potent instrument in making the transition was the national academies. The French Academy was founded in 1666. It published in French. The Royal Society of London was established in 1662 and its *Philosophical Transactions* have been published in English from 1665 to the present. The Berlin Academy (1700–), however, published for many years in Latin.

SYNTHETIC LANGUAGES.

Latin is dead as a scientific language. It possesses all the difficulties of a modern ethnic language, plus a grammatical complexity that modern languages have long since abolished. Furthermore, classical Latin lacks thousands of technical words that are required in science and engineering. What the world needs is a universal auxiliary language that can be learned by anyone, anywhere, in a minimum of time.

The famous mathematician, Gottfried Wilhelm Leibniz (1646–1716), spent much thought on a universal scientific language. He was inter-

ested primarily in an artificial language that could be used as a precision tool in philosophical and logical research (2). He felt that Latin, which had grown up in a haphazard manner, was too blunt a tool to satisfy the needs of the future. Descartes had a similar idea in 1629, but neither man tried actually to devise such a language. Bishop Wilkins, one of the founders of the Royal Society, developed an *a priori* artificial language in 1668. Dalgarno, Sudre, Ochando, and others worked out similar projects, all of which were found to be impracticable because of the difficulty in memorizing the synthetic words, which had no resemblance to existing words in the ethnic languages (4).

The first artificial language to be learned and used by all kinds of people was Volapük, invented by a priest, Johann Martin Schleyer (4), in 1879. Its vocabulary was based largely on English, but with the

TABLE III.—*Some Important Universal-Language Projects.*

Author	Date	Name of Language	Principal Basis for Vocabulary
Réné Descartes	1629	—	—
G. W. Leibniz	1702	—	—
George Dalgarno	1661	—	Synthetic
John Wilkins	1668	—	Synthetic
François Sudre	1817	Solresol	Synthetic
Sotos Ochando	1852	Langue universelle	Synthetic
J. M. Schleyer	1879	Volapük	English
L. L. Zamenhof	1887	Esperanto	Latin
Giuseppe Peano	1903	Latino	Latin
L. de Beaufront W. Ostwald O. Jespersen G. Peano L. Couturat L. Leau	1907	Ido	Latin
Edgar de Wahl	1922	Occidental	Latin
Otto Jespersen	1928	Novial	Latin
Int. Aux. Lang. Assn.	—	Iala	Latin

words so shortened as to be unrecognizable in most cases. Despite its peculiar words and its complicated grammar, Volapük seemed to fill a human need and it achieved an immense success. Volapük clubs were formed throughout Europe and international congresses were held. Today, however, Volapük has been superseded by other languages.

The principal artificial languages at the present time (4) are *Esperanto* (5), *Latino sine Flexione* (6), *Ido* (7), *Occidental* (8), and *Novial* (9) (Table III). Hundreds of other artificial languages have been developed, however, and a bibliography (10) of over 6000 items is available. Rather than discuss the differences in these languages, we shall pursue the more fruitful course of indicating what they have in common. As Otto Jespersen pointed out (9), artificial languages are converging to a common mean, so that any new development that makes use of previous research will differ from the others by less than the differences that exist

between dialects of a single ethnic language. In other words, the five formulations named above (and many others) are merely *variations of a single international language.*

Some characteristics of this language are as follows:

1. The language is *phonetic*, so that difficulties in spelling and pronunciation are eliminated. In place of the large number of vowel sounds existing in French and in English, the international language employs only five:

a always as in	*father*,
e	*met*,
i	*machine*,
o	*rose*,
u	*rule*.

The consonants are generally pronounced as in English.

2. Sounds that are difficult for any nationality are omitted. These omissions include the *th* of English, the *ü* and *ö* of German, the gutteral *ch*, and some consonant clusters that occur in Polish and Czech.

3. The vocabulary is based principally on Latin. This choice of words lightens the memorizing task for anyone who knows English, French, Italian, Spanish, or Portuguese. In Latino (6), the vocabulary is almost entirely Latin, while in Esperanto, Ido, and Novial it contains words also from German, Russian, and other sources.

4. International words are accepted. This includes many scientific words, as well as such words as *taxi*, *aeroplane*, *academy*, *chocolate*, *coffee*, *hotel*, *jazz*, *cabaret*.

5. Grammar is greatly simplified. Irregular verbs are abolished, grammatical gender is eliminated, case endings are generally omitted, and everything is covered by invariable rules. Peano said (6), "La grammatica minima è la grammatica nulla," though most versions of the international language have not yet reached this ideal.

All the modern versions agree on these five points and are therefore very similar. And any of them is immensely easier to learn than a natural language. Any one of the five could be adopted today by an international organization, to the great advantage of mankind.

Many people seem to feel, however, that ten or twenty years further study of the problem will suddenly reveal something different and vastly superior. It is practically certain that such is not the case. In an international language, every word is a compromise, every rule is a compromise—a compromise between logical simplicity and "naturalness" or among the needs of several language groups. The ethnic languages are not simple and they are not logical. Thus, at every step, the maker of an international language must choose between what appears obvious and natural and what is simple and regular. He must also balance the requirements of speakers of different languages so that

the new language is not too difficult for any group. At every step a choice must be made and this choice is arbitrary. In Occidental (8), most choices have been made in favor of what is "natural" for speakers of the Romance languages; while in Esperanto (5) and Ido, the choice has usually favored simple, invariable rules rather than naturalness. Different people favor different compromises, which is the reason for the five variants and many others. But the important point is that no further research can possibly change this fundamental fact—*the international language is necessarily an arbitrary compromise.* Let us start using whichever of the dialects appears most attractive (11), secure in the knowledge that it is a dialect of *the* international language that will some day become the official auxiliary language of the world.

SCIENTIFIC AND POPULAR NEEDS.

The international auxiliary language was developed primarily for popular use. Evidently, the language difficulties of tourists, business men, and delegates to international gatherings would be eliminated if everyone knew two languages—his native tongue and the international auxiliary language.

The language problem confronting the human race is a very real one. As Guerard (4) says, "The fact which seems to blind us with excess of evidence is that the language obstacle is most emphatically not a theory but a condition." It is inconceivable that the human animal has insufficient brains to solve the problem. It must be done, and the only feasible method seems to be the use of an auxiliary language. This language can be taught in the elementary schools so that within a generation every literate person would know it. The study of the international language is of considerable cultural value and is an excellent preparation for the study of an ethnic language. The use of the national languages would not be affected by the study of the auxiliary language.

In contradistinction to this idea of a popular international language, we have the Descartes-Leibniz conception of a constructed language for precise scientific use. There seems to be no reason, however, why these two ideas cannot be combined. Among scientists who have worked toward the establishment of the universal scientific language are Wilhelm Ostwald, Nobel prize winner in chemistry; W. Rosenberger, Russian engineer; Giuseppe Peano, outstanding Italian mathematician; Couturat and Leau, French logicians and mathematicians; Eugene Wüster, Austrian engineer; F. G. Cottrell, American chemist and inventor.

Esperanto or Ido may not have quite the precision that Leibniz had in mind, but it is greatly superior to any of the ethnic languages in that respect. Any English-speaking person who has tried scientific writing in the international language is impressed by how vague, inexact, and

sloppy is English in comparison with the constructed language. French has the reputation for logic and clarity, but it cannot compare in that respect with the artificial language.

Thus to obtain a universal scientific language, we need only take one of the variants devised for popular use. Such a procedure has the advantage that it will never get the scientist into the trouble that was experienced with Latin. Unlike Latin, the international language is easy to learn and is a language of the people.

ADVANTAGES.

The foremost advantages to be gained by the use of a universal scientific language are

1. Internationality,
2. Clarity.

The advantages of scientific publication in a single language instead of a dozen languages is obvious. The possibilities of direct communication—by telephone, cable, letter—among scientists and technicians throughout the world are of far-reaching consequence. The standardization of nomenclature, symbols, weights and measures has always been hampered by the lack of a universal language. Usually, international technical conferences are conducted in three languages (12), with consequent loss of time and frequent misunderstandings. All these difficulties would be eliminated by the use of an international auxiliary language (13).

The foregoing advantages are self evident. Less obvious is the advantage of *clarity*. In this respect, the principal difference between the constructed language and the natural languages is the smaller number of meanings attached to a given word in the constructed language. In fact, the attempt is made to have only one meaning for each word instead of the dozen or more meanings sometimes associated with an English word. Semantics (14) teaches some of the dangers to exact thought hidden in the four meanings of "is" and in multiple meanings of most other words. The constructed language does not eliminate all these possibilities of misunderstanding but it does make for more exact scientific thought. In the elimination of ambiguity, one may mention also the proposed international names of scientific concepts (15), used either with the ethnic languages or with the international language.

As a single example of the innumerable ones that might be written, consider the English preposition *of* and its equivalents in Esperanto (16).

1. "Two *of* the three generators were inoperative."
   Esperanto—*el* (part of a whole).
2. "The cost *of* electric energy is being reduced."
   Esperanto—*de*.

3. "Add 1.2 liter *of* water."
   Esperanto—*da* (measure of amount).
4. "He was glad *of* it."
   Esperanto—*pro* (because of).
5. "The article contains nothing *of* interest."
   No preposition used in Esperanto.
6. "The machinery was ordered by the City of Los Angeles."
   No preposition used in Esperanto.

SUMMARY.

Because of the vital importance of science and technology in the modern world, an international language for scientific publication and scientific intercourse is needed as never before. For five centuries, the need was satisfied by Latin; but for the past hundred years, the world has had no international language and the linguistic condition has become steadily more muddled.

During the last eighty years, a large amount of research has been devoted to devising an international auxiliary language, and a number of satisfactory projects have been developed. It is encouraging to note that all the modern variants have much in common and are really all dielects of *the* international language. In the absence of authoritative international agreement on the exact details of the universal auxiliary language, one may study any one of them with the belief that whatever variant is finally standardized will not differ much from the forms now available.

A simple example of Esperanto text is now given, with its English translation.

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Esperanto:

LA LEĜO DE OHM.

Konsideru metalfadenon de unuforma sekcio, kaj kunligu ĝin al baterio. La baterio konservas konstantan elektran tension trans la ekstremaĵojn de la fadeno kaj produktas konstantan elektran fluon tra la fadeno. Se ni ŝanĝus la elektran tension, la fluon ŝanĝus ankaŭ.

Ni konduktas eksperimenton: ni uzas plurajn valorojn de elektra tensio kaj ni mezuras la fluon pro ĉiu tensio. Se la temperaturo de fadeno estas konstanta, kaj ni duobligas la tensio, ni trovas, ke duobliĝas ankaŭ la fluo. Matematike, oni skribas

$$I = V/R,$$

kie R estas konstanto, kiu dependas je la materialo de la fadeno kaj je ĝiaj dimensioj. La konstanto R estas nomata, la *resisto*. La matematika ekvacio estas la *lego de Ohm*.

English:

OHM'S LAW.

Consider a metal wire of uniform cross-section, and connect it to a battery. The battery maintains a constant voltage across the ends of the wire and produces a constant electric current through the wire. If we change the voltage, the current changes also.

We conduct an experiment: we use several values of voltage and we measure the current for each voltage. If the temperature of the wire is constant and we double the voltage, we find that the current doubles also. Mathematically, one writes

$$I = V/R,$$

where R is a constant that depends on the material of the wire and on its dimensions. The constant R is called the *resistance*. The mathematical equation is *Ohm's law*.

The use of a universal language for all scientific publication may seem visionary, but it is really as feasible as it is inevitable. Obviously the change cannot be made in a day. But any scientist or engineer can help to bring it about by:

(*a*) Learning the language. Many excellent textbooks and dictionaries are available, and classes are held in the larger cities. Phonograph records and international-language broadcasts may also be used.

(*b*) Teaching the language. Most people find it to be a fascinating subject. Even divorced from any practical application, it is excellent mental training, gives an insight into the structure of English and other languages, is splendid preparation for the study of natural languages, and is fun.

(*c*) Publishing extracts in the language. An international scientific journal, giving abstracts (in the international language) of scientific papers appearing in all languages would be a step toward the eventual publication of all scientific papers in the universal language. As a still humbler beginning, one may consider the possibility of publishing IL summaries of his own papers as they appear in existing journals. The Bulletin Française des Electriciens, for instance, published abstracts in Esperanto; and it is possible that other journals will do likewise.

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MEASUREMENT OF THE DIELECTRIC PROPERTIES OF SOILS AND WATER AT 3.2 CM. WAVE LENGTH.*

BY

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I. INTRODUCTION.

1. A knowledge of the dielectric properties of soils and water is essential in the study of the propagation of radio waves through these materials or through the atmosphere adjacent to them. The dielectric properties measured at relatively long wave lengths require reevaluating for the recently introduced wave lengths of a few centimeters.

2. This paper describes the measurement of the dielectric constant and the conductivity of certain soils and water at a wave length of 3.2 cm. Particular attention is given to the measurement of the dielectric properties of the soil on the Navy Electronics Laboratory's Radio Site near Gila Bend, Arizona.

3. The measurements described in the present paper are believed to be the first made in the microwave region by actually measuring the phase shift and attenuation of a radio wave traveling through a sample of the material. Other measurements in this region have been made by a combination of reflection and transmission measurements (**2**, **3**, **4**).[2]

II. MEASUREMENT PROCEDURE.

1. Equipment Arrangement. The phase difference equipment designed by the Electrical Engineering Research Laboratory for phase front and angle-of-arrival measurements was used (**1**). The phase difference equipment indicates changes in relative phase of X-band signals applied to its two channels. This is accomplished by heterodyning the microwave signals down to 12 mc. and applying them to a cathode ray tube. The 12-mc. signal from one of the channels is applied to the horizontal and vertical deflection plates in such a manner as to produce a circle and the 12-mc. signal from the other channel applied is to the control grid of the cathode ray tube. This produces an arc on the screen of the cathode ray tube which is displaced around the screen of the tube in proportion to the phase difference between the microwave signals applied to the two channels. The materials whose dielectric constant and conductivity were to be measured were introduced between the signal source and one of the channels. The resulting changes in

* Prepared under U. S. Navy Contract N5ori-136, T. O. 1.

[1] Electrical Engineering Research Laboratory, The University of Texas, Austin, Tex.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

relative phase and attenuation, produced by varying the thickness of the materials, were plotted. An example of these curves is shown in Fig. 1.

2. Calculations. The dielectric constant and conductivity were determined from the curves of phase shift and attenuation *versus* material thickness as follows:

The attenuation and phase shift per meter due to the presence of the sample were determined from the slope of the best straight lines drawn through the points of the graphs as shown in Fig. 1. Since the transmission loss was negligible before the sample was inserted, the attenua-

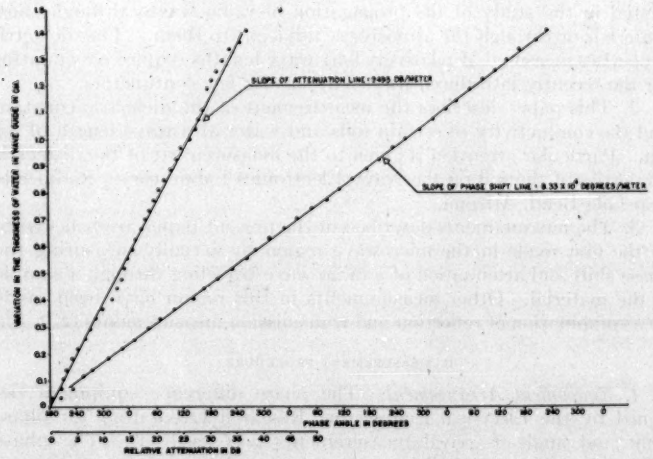
SLOPE OF ATTENUATION LINE = 2495 DB/METER
SLOPE OF PHASE SHIFT LINE = 8.33 X 10³ DEGREES/METER
PHASE ANGLE IN DEGREES
RELATIVE ATTENUATION IN DB

FIG. 1. Phase shift and attenuation produced by various thicknesses of distilled water.

tion, α, in nepers [3] per meter was determined directly from the graph. However, the phase shift in radians per meter due to the air path was added to the phase shift due to the insertion of the sample to get the total phase shift per meter, β.

The expressions for attenuation, α, and phase shift, β, are given in numerous textbooks as functions of the dielectric constant, k, and conductivity, σ, since k and σ are usually considered to be known data. These relationships for free space may be found in Stratton's "Electromagnetic Theory," p. 276 and for a rectangular wave guide may be found in Ramo and Whinnery's "Fields and Waves in Modern Radio,"

[3] Attenuation in nepers is the natural logarithm of the ratio of the field intensities and is equal to 0.115 times the attenuation in decibels.

p. 345. By simple algebraic transformations, k and σ may be expressed in terms of α and β as shown below:

Free space equations:

$$k = (\beta^2 - \alpha^2)(\lambda/2\pi)^2$$
$$\sigma = \alpha\beta\lambda/\pi n.$$

Wave guide equations:

$$k = (\lambda\beta/2\pi)^2 + (\lambda/2a)^2$$

$$\sigma = \frac{2\alpha}{n}\sqrt{k - (\lambda/2a)^2}$$

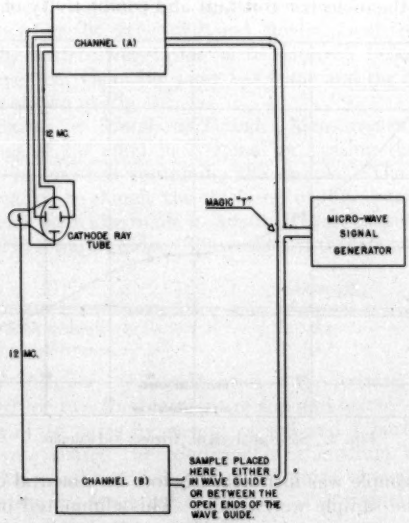
CHANNEL (A)
12 MC.
CATHODE RAY TUBE
MAGIC "T"
MICRO-WAVE SIGNAL GENERATOR
12 MC.
CHANNEL (B)
SAMPLE PLACED HERE, EITHER IN WAVE GUIDE OR BETWEEN THE OPEN ENDS OF THE WAVE GUIDE.

FIG. 2. Apparatus for measuring dielectric characteristics.

Where λ = the wave length in air (0.0322 m.)
n = the intrinsic impedance of air (377 ohms)
a = the rectangular guide width (0.0228 m.).

3. Location of Sample. Three arrangements for measuring the samples were used as follows:

a. By supplying a signal to the two channels through wave guide from a common signal source and placing the material in the wave guide supplying one of the channels.

b. By supplying a signal to the two channels through wave guide from a common source and placing the material between open ends of the wave guide feeding one of the channels.

c. By supplying a signal to the two channels from a signal source 400 ft. from their antennas and placing the material between 3-ft. square glass plates adjacent to and in front of the antenna of one channel.

The apparatus arrangement for methods (a) and (b) was as shown in Fig. 2. The arrangement for (c) was the same except for the 400-ft. propagation path between the generator and the two channels.

4. Reduction of Reflections. In each of the three arrangements used for measuring the dielectric constant and conductivity of the materials,

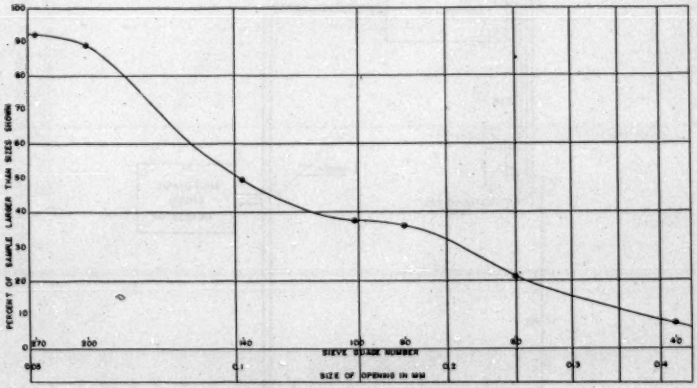

FIG. 3. Sieve analysis of Arizona soil sample.

a fairly large sample was introduced before incremental changes in the thickness of the sample were made. This eliminated or reduced the effect on the measured values of phase shift and attenuation of the reflected signal from the discontinuity at the two faces of the samples.

5. Soil Sample Methods. The soil samples were measured by using the three methods above and also by filling a slotted section with a sample and taking off the signal for one of the channels with a traveling wave detector, thereby measuring the wave length in the soil-filled wave guide. The wave length was measured by observing the displacement of the traveling wave detector required to produce a 360° rotation of the arc on the screen of the cathode ray tube.

6. Water Sample Methods. The characteristics of the water samples were measured by placing the sample in a glass tray with one open end

of the wave guide directly beneath the tray and the other open end a short distance above the water. The measurements were repeated with the upper wave guide pushed into the water against the tray. Water was added to the tray in small increments and was permitted to rise in the wave guide.

7. Agreement of Results. The measured values of dielectric constant and conductivity agree to two significant figures for the various methods of measurement. The attenuation due to the losses in the walls of the wave guide was negligible as compared to the losses in the dielectric.

III. MEASUREMENTS OF ARIZONA SOIL.

1. Nature of Sample. The soil sample used was obtained on the Navy Electronics Laboratory's Desert Site near Gila Bend, Arizona. The soil was ordinarily very dry and finely powdered. Scattered pebbles and the surface vegetation were removed before taking the sample. A sieve analysis of the sand was made and the distribution of particle sizes is shown in Fig. 3.

2. Measurements on Sample as Found. Measurements were made on a large mass of the sand in Arizona by passing the microwaves through a 3-ft. square box containing the sample. The separation of the walls was varied to change the thickness of the sample.

Measurements were also made in Austin, Texas, by putting a sample of the same soil in a wave guide. The results of these measurements are as follows:

	Dielectric Constant	Conductivity, Mhos per meter
Wave guide measurements	3.2	0.10
Larger mass measurements	3.2	0.10

3. Effect of Moisture. The properties of the Arizona soil when wet were considered for two combinations of soil and water. The first was a combination of 16 parts by weight of soil and 1 part by weight of water. This represented the condition of a medium wet soil. The second condition considered was that of 4 parts of sand to 1 part of water representing the saturated condition. The results of these measurements are as follows:

	Dielectric Constant	Conductivity, Mhos per meter
16 parts sand, 1 part water	8.1	1.1
4 parts sand, 1 part water	19	2.5

4. Effect of Particle Size. The soil samples as separated by the sieve analysis were tested individually with the following results:

Particle Size	Dielectric Constant	Conductivity, Mhos per meter
Between 2.00 and 0.42 mm	3.2	0.086
Between 0.42 and 0.25 mm	3.0	0.091
Between 0.105 and 0.074 mm	3.0	0.103

5. Effect of Packing of Sample. The increasing loss with decreasing particle size seemed to be due to increased packing of the sample due to the smaller size. As a check of this, the middle sample in the list above was remeasured with extremes of packing with the following results:

	Dielectric Constant	Conductivity, Mhos per meter
Very loosely packed	2.7	0.07
Very tightly packed	3.0	0.12

IV. MEASUREMENT OF SOIL SAMPLES FROM AUSTIN, TEXAS.

1. Black Sandy Loam. A sample of sandy loam from the ground surface near the plant of the Electrical Engineering Research Laboratory was baked dry and its constants measured. One part of water was then added to ten parts of soil by weight and the measurements repeated. The results of these tests are as follows:

	Dielectric Constant	Conductivity, Mhos per meter
Black sandy loam, very dry	2.8	0.0074
Black sandy loam, 1 part of water to 10 parts of soil	4.6	0.22

2. Colorado River Sand and Gravel Mix. The dielectric characteristics of sand and gravel mix were measured with the following results:

	Dielectric Constant	Conductivity, Mhos per meter
Sand and gravel mix	3.0	0.0072

V. DISCUSSION OF SOIL SAMPLE MEASUREMENTS.

1. Comparison of Results. Ford and Oliver (2) reported a value of dielectric constant of 2 and conductivity of 0.033 mhos per meter for very dry sandy loam at 9 centimeters. This is in the same range as measured for Arizona and Austin soil samples. The Arizona soil samples showed a conductivity about 3 times as high as Ford and Oliver's value while the Austin soil conductivity was approximately one-fourth their value.

2. Iron Content of Arizona Soil. The Arizona soil contained a considerable amount of iron as shown by iron slivers sticking to a magnetized screw driver. This was evident in the larger sizes only and did not appear in the particles which passed through a 140 mesh screen (0.105-mm. openings). The relative permeability was measured at 550 kilocycles to be approximately 1.01 and was, therefore, taken as 1 in the calculations.

VI. WATER SAMPLES.

1. Measurements. Measurements of the dielectric constant and conductivity were made on distilled water and on a sample of water from

the Gulf of Mexico by transmission through a shallow tray and by filling a wave guide. Identical results for the two methods were obtained and are shown below.

Sample	Dielectric Constant	Conductivity, Mhos per meter
Fresh water (23° C.)	67	12
Sea water (28° C.) (2.2 per cent salt)	65	16

2. Discussion. The measurements for fresh water agree fairly closely with the value of 72 for dielectric constant and the value of 13.1 mhos per meter for conductivity as obtained from Saxton's work (3) for 3.2 cm. and 25° C.

The salt water sample was obtained from the surface layer on the Gulf side of Galveston Island and contained a lower than average salt content because of the method of sampling. The measured value of conductivity of 16 mhos per meter agrees very well with the value of 17 suggested by von Hippel (4) for sea water, but the dielectric constant of reference 4 is 35 as compared with the authors' measurement of 65. The relatively small effect of the salt concentration on the values is shown by the conductivities of 12 and 16 and dielectric constants of 67 and 65 for fresh and sea water, respectively.

VII. SUMMARY.

The dielectric properties of soils and water at 3.2 cm. wave length as measured by the Electrical Engineering Research Laboratory are listed in the following table:

Sample	Dielectric Constant	Conductivity, Mhos per meter
Arizona Soil		
1. As found	3.2	0.10
2. 16 parts soil and 1 part water	8.1	1.1
3. 4 parts soil and 1 part water	19	2.5
4. Particle size: 0.42 to 2.00 mm.	3.2	0.086
5. Particle size: 0.25 to 0.42 mm.	3.0	0.091
6. Particle size: 0.074 to 0.105 mm.	3.0	0.104
7. Very loosely packed Particle size: 0.25 to 0.42 mm.	2.7	0.07
8. Very tightly packed Particle size: 0.25 to 0.42 mm.	3.0	0.12
Austin, Texas Soil		
9. Very dry	2.8	0.0074
10. 10 parts of soil to 1 part of water	4.6	0.22
11. Colorado River sand and gravel mix	3.0	0.0072
Water		
12. Fresh (23° C.)	67	12
13. Sea (28° C.) (2.2 per cent salt)	65	16

VIII. REFERENCES.

(1) F. E. BROOKS, JR., AND C. W. TOLBERT, "Equipment for Measuring Angle-of-Arrival by the Phase Difference Method," *Elec. Eng. Research Lab.*, Report No. 2, May, 1946.

(2) L. H. FORD AND R. OLIVER, "An Experimental Investigation of the Reflection and Absorption of Radiation of 9 cm. Wave Length," *Proc. Phys. Soc.*, Vol. 58, Part 3, May, 1946.

(3) J. A. SAXTON, "The Dielectric Properties of Water at Wave Lengths From 2 mm. to 10 cm. and Over the Temperature Range 0° C. to 40° C.," *Radio Research Board*, Paper No. R.R.B./C. 115.

(4) W. T. FISHBACK AND P. J. RUBENSTEIN, "Further Measurements of 3- and 10-cm. Reflection Coefficients of Sea Water at Small Grazing Angles," *Radiation Lab.*, Report No. 568, Mass. Inst. Tech.

STABILIZATION OF CARRIER-FREQUENCY SERVOMECHANISMS. I. GAIN-PHASE MARGIN DIAGRAMS OF CONTROLLER CHARACTERISTICS.*

BY

ANDREW SOBCZYK, Ph.D.[1]

ABSTRACT.

In this first part a method of analysis of linear carrier-frequency systems is indicated, and applied in particular to electrical servomechanisms using a two-phase alternating-current control motor. The performance of such a servo, as regards stability and fidelity of the output as a copy of the input, depends on the action of a controller-demodulator unit including the motor. A calculation of the steady-state effect of a linear transfer characteristic on the suppressed-carrier modulated error signal makes possible application of the Nyquist stability criterion.

The method does not require symmetry of the characteristics about the carrier frequency; if such symmetry is present the system is similar to an ordinary or d-c. servo. Thus a band-rejection network tuned to the carrier frequency has an approximate proportional plus derivative action on the envelope of the error signal, resulting in an "anti-hunt" or stabilizing effect similar to that due to a translated band-rejection characteristic (center at zero-frequency) in a corresponding d-c. servo.

A procedure is given for construction of transformed Nyquist diagrams, or gain-phase margin diagrams. The effect of the correctly tuned band-rejection network, as well as the effects of bandwidth, of the network being tuned off the carrier frequency, of increasing gain or velocity constant k_v, and of the use of phase-shifting networks, are clearly shown by a series of such diagrams.

1. INTRODUCTION.

A servomechanism is a power-amplifying device, employing a feedback arrangement, by means of which the error, or difference of the input and output quantities, controls a motor which drives the output in such a manner as to maintain the error as nearly zero as possible.

In an ideal servomechanism, the output would be an exact power-amplified copy of the input, without time delay, whatever the form of the independent input as a function of time. Thus for sinusoidal inputs an ideal servomechanism would have a flat frequency amplitude characteristic, and zero phase shift at all frequencies.

The problem of servomechanism design is to obtain high power gain with small time lag of the output in following the input quantity, and with satisfactory freedom from a tendency toward instability or "hunting," that is freedom from excitability of steady or only slightly damped

* This paper and Parts II and III to follow in the August and September issues consist essentially of the material contained in the author's Radiation Laboratory report, No. 811, "Parallel 'T' Stabilizing Networks for AC Servos."

[1] Formerly with Radiation Laboratory, Massachusetts Institute of Technology; now at Watson Laboratories, Cambridge Field Station, Cambridge, Mass.

oscillations of the output. In a servomechanism which is properly designed and adjusted, the output quantity is a "slave" of the independent input quantity. These requirements will be met if the frequency-phase characteristic is a sufficiently good approximation to the ideal characteristic of identical transmission at all frequencies.

The theory and analysis of ordinary servomechanisms, based on the steady state response to sinusoidal inputs, has been presented by A. C. Hall in a recent paper in this JOURNAL (1).[2]

A servomechanism may be of a mechanical, hydraulic, pneumatic, or electrical nature, or a combination of elements of two or more kinds. A d-c. servomechanism, requiring a d-c. control amplifier, is indicated in Fig. 1. The input θ_i and output θ_o are potentiometer shaft rotations.

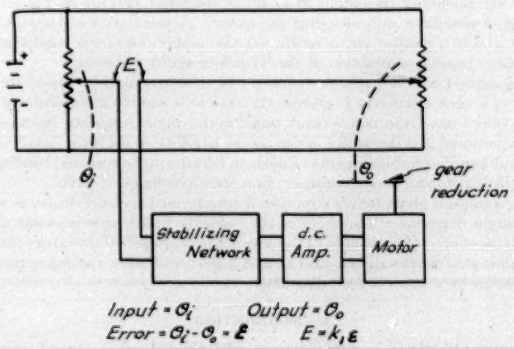

FIG. 1. A d-c. servomechanism.

The error voltage is the difference of potential between the contact arms of the linear input and output potentiometers. This voltage drives the d-c. motor to correct the error, through a stabilizing network and the d-c. amplifier. With a stabilizing or anti-hunt network well suited to the time lag characteristics of the d-c. motor and amplifier, and suitable gear reduction, the output θ_o will be a faithful copy of the input θ_i, and will be capable of driving a heavy load.

It is well known that the design of a stable d-c. amplifier (to drive a d-c. motor) requires extreme care (it is in itself a problem of the same nature as the design of a servomechanism, with added difficulties), and the construction of the amplifier is expensive; while the design of a high-gain, ordinary resistance-coupled feedback audio amplifier (satisfactory for driving an a-c. motor at say the standard frequency of 60

[2] The boldface numbers in parentheses refer to the references appended to this paper.

cps.) is easy, and the construction inexpensive. For most applications it is therefore highly advantageous to use a-c. servomechanisms.

Figure 2 is a schematic drawing of an a-c. servomechanism of the

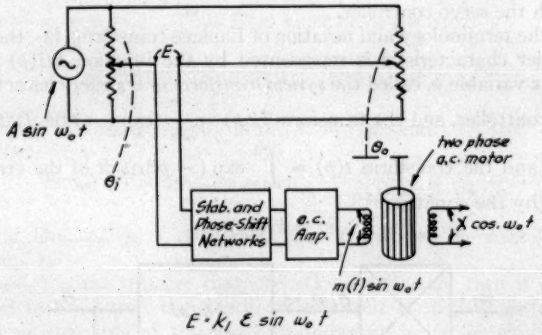

FIG. 2. An a-c. servomechanism.

general type which the writer had in mind when developing the analysis contained in this paper. The potentiometers may be replaced by selsyns in the standard generator-control transformer connection (Fig. 3).

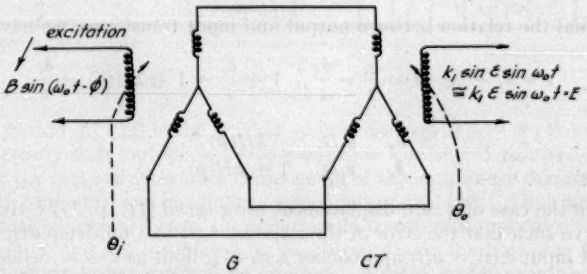

FIG. 3. Connection of selsyn generator and control transformer (to replace potentiometers in Fig. 2).

In both Figs. 1 and 2, the driven load on the output shaft θ_o is not shown. This load of course may have a large effect on the nature of the stabilizing characteristic which is desirable.

2. SERVO AND SERVO CONTROLLER; STABILITY.

Figure 4 is a familiar general diagram for a linear servo, which includes as instances the linear approximations to the d-c. and a-c. servos

of Figs. 1 and 2. The input and output are subtracted in the symbol for a differential gear, and the difference or error $\epsilon = \theta_i - \theta_o$ is fed into the portion of the servo marked $kH(p)$. This portion is called the *servo controller*. The output $\theta_o(t)$ is determined by the error $\epsilon(t)$ acting through the servo controller.

In the terminology and notation of Laplace transforms (2), the servo controller characteristic is represented by the function $kH(p)$ of the complex variable p, called the *system transform* or transfer characteristic of the controller, and the transform $\bar{\theta}_o(p) = \int_0^\infty \exp(-pt)\theta_o(t)dt$ of the output and the transform $\bar{\epsilon}(p) = \int_0^\infty \exp(-pt)\epsilon(t)dt$ of the error are related by the equation

$$\bar{\theta}_o = kH(p)\bar{\epsilon}. \tag{1}$$

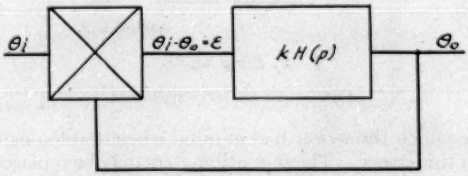

FIG. 4. General servo diagram.

To find the relation between output and input transforms, we have

$$\bar{\epsilon} = \bar{\theta}_i - \bar{\theta}_o, \quad 1 = \frac{\bar{\theta}_i}{\bar{\epsilon}} - \frac{\bar{\theta}_o}{\bar{\epsilon}}, \quad 1 + \frac{\bar{\theta}_o}{\bar{\epsilon}} = 1 + kH(p) = \frac{\bar{\theta}_i}{\bar{\epsilon}}, \tag{2}$$

and

$$\frac{\bar{\theta}_o}{\bar{\theta}_i} = \frac{\bar{\theta}_o/\bar{\epsilon}}{\bar{\theta}_i/\bar{\epsilon}} = \frac{kH(p)}{1 + kH(p)}. \tag{3}$$

In the case of a zero displacement error servo [(1), p. 297], that is, a servo such that the error of the response $\theta_o(t)$ to a unit-step displacement input $\theta_i(t) = u(t)$ approaches zero as a limit as $t \to \infty$, while the error for an instantaneous velocity input $\theta_i(t) = \int_0^t u(t)dt$ [equals t for $t \geqq 0$, equals 0 otherwise] does not approach zero, $H(p)$ may be normalized so that the gain constant k is the velocity error constant k_v (equals reciprocal of the limiting time lag of θ_o behind θ_i for an instantaneous velocity input). For if $\theta_i = u(t)$, the unit step at $t = 0$, then $\bar{\theta}_i = 1/p$, and from (2) above

$$\frac{\bar{\epsilon}}{\bar{\theta}_i} = \frac{1}{1 + kH(p)}, \qquad \bar{\epsilon} = \frac{1}{p[1 + kH(p)]}.$$

By the final-value theorem for Laplace transforms [(2), p. 265],

$$\lim_{t\to\infty}\epsilon(t) = \lim_{p\to 0} p\bar{\epsilon} = 0 = \lim_{p\to 0}\frac{1}{1+kH(p)},$$

$kH(p) \not\to \infty$ as $p \to 0$. Thus $H(p)$ must be of the form

$$\frac{A(p)}{p}, \qquad A(0) \neq 0 \quad \text{and} \quad \neq \infty.$$

For an instantaneous velocity input, $\bar{\theta}_i = 1/p^2$, and

$$\lim_{t\to\infty}\epsilon(t) = \lim_{p\to 0} p\bar{\epsilon} = \lim \frac{1}{p + pkH(p)} = \frac{1}{kA(0)}.$$

Thus if $\lim_{p\to 0} pH(p) = A(0) = 1$, then k will be the velocity error constant k_v.

If $G(p)$ is the transfer characteristic of a system, then if $\cos \omega t$ is applied to the input, the steady-state output is $|G(j\omega)|\cos(\omega t + \phi)$, and if $\sin \omega t$ is applied, the steady-state output is $|G(j\omega)|\sin(\omega t + \phi)$, where $\phi = \angle G(j\omega)$. For by the convolution and inversion theorems [(2), pp. 228, 105] if $\exp(j\omega t)$ is applied to $G(p)$, the output is

$$\int_0^t e^{j\omega(t-\tau)}g(\tau)d\tau = e^{j\omega t}\int_0^t e^{-j\omega\tau}g(\tau)d\tau$$

$$= e^{j\omega t}\left[\int_0^\infty - \int_t^\infty\right] = e^{j\omega t}\left[G(j\omega) - \int_t^\infty\right],$$

where

$$g(\tau) = (2\pi j)^{-1}\int_{\tau-j\infty}^{\tau+j\infty} e^{p\tau}G(p)dp.$$

The second integral in the bracket approaches zero as $t \to \infty$; therefore the steady-state output is $G(j\omega)\exp(j\omega t)$. The stated results follow since the real and imaginary components of this output are due respectively to the real and imaginary components of $\exp(j\omega t)$. Thus in dealing with sinusoidal inputs, the equations in transforms apply also to the time functions if p is replaced by $j\omega$. Accordingly the bars over θ_o, θ_i, ϵ indicating transforms will be omitted. A ratio, as for example θ_o/ϵ, for each ω is a complex number of which the magnitude and angle are, respectively, the amplitude and phase of the output when the error ϵ is a unit sinusoid of frequency ω.

The plot of $\theta_o/\epsilon = kH(j\omega)$ in the complex plane, as ω ranges from 0 to ∞, is the well-known Nyquist diagram for the servo. If the origin is shifted to the point -1, the same plot is also the graph of θ_i/ϵ, since $\epsilon = \theta_i - \theta_o$, or $1 = \theta_i/\epsilon - \theta_o/\epsilon$ (see Fig. 5).

The degree of stability of the servo is expressed by the peak height of the frequency characteristic, that is the value of $M = \max|\theta_o/\theta_i|$.

The greater the value of the ratio M, the less stable is the servo. Also, for any particular application, of course the frequency ω for which the maximum value M is attained, is important. Stability corresponding to values of M between 1.0 and 2.0 usually is satisfactory. A general design rule is stated on p. 287 of (1).

In the Nyquist plane, the system of curves of equal values of the ratio $M = |\theta_o/\theta_i|$ are circles of diameter $(M + 1)^{-1} + (M - 1)^{-1}$, with centers at $-1 - \frac{1}{2}[(M - 1)^{-1} - (M + 1)^{-1}]$. These circles are plotted in Fig. 6 on p. 291 of (1). Given the Nyquist graph for a stable servo, the peak height M of the frequency-amplitude characteristic is the value of M for that circle of the system which is just tangent to the graph. The transition between stability and instability of a servo occurs as the gain is varied so that the Nyquist graph passes through the point -1 (where the ratio θ_o/θ_i becomes infinite).

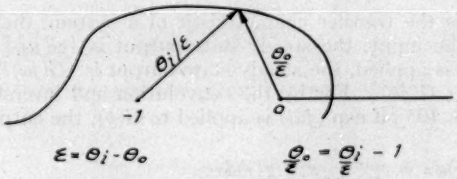

FIG. 5. A Nyquist diagram.

For easy determination of appropriate values of the gain factor k, and also for other reasons, it is advantageous for our purposes to transform the Nyquist plane and diagram as follows. The *phase margin* is the difference of phase between θ_o/ϵ and the phase π of the critical point -1. The rectangular coordinates in the transformed plane are the gain ratio $|\theta_o/k\epsilon|$ expressed in decibels, and the phase margin $\pm [\angle (\theta_o/\epsilon) - \pi]$. For any controller characteristic $kH(p)$, the transformed Nyquist graph is obtained by plotting $20 \log|H(j\omega)|$ *versus* the phase margin $\pm [\angle H(j\omega) - \pi]$, with frequency ω as parameter. Let the chart with this graph be referred to as A.

Figure 6 gives the curves which correspond, under the above transformation of the Nyquist plane (the rectangular coordinates are $|\theta_o/\epsilon|_{db}$ and $\phi = \angle (\theta_o/\epsilon) - 180°$), to the system of circles of equal values of M. To determine the gain possible without exceeding a specified peak M, and the frequency at which the peak is attained, Fig. 6 is superposed on A and translated up or down until the curve corresponding to the desired peak $|\theta_o/\theta_i| = M$ just touches the graph in A. The position of $0\ db$ in Fig. 6 on A then is read, to determine the value of the gain factor k in decibels. If $0\ db$ in Fig. 6 corresponds to $-x\ db$, then $20 \log k = x$.

This follows since $20 \log |H(j\omega)| = 20 \log |\theta_o/k\epsilon| = 20(-\log k + \log |\theta_o/\epsilon|)$ $= -|k|_{db} + |\theta_o/\epsilon|_{db}$. (For the sliding process it would be convenient to have the curves of Fig. 6 on a sheet of transparent material.)

The ratio of error to input, $E = |\epsilon/\theta_i|$, for any gain setting k and any frequency of the input, may be read by comparing the graph of the servo controller in A with the dashed-line curves in Fig. 6. (The

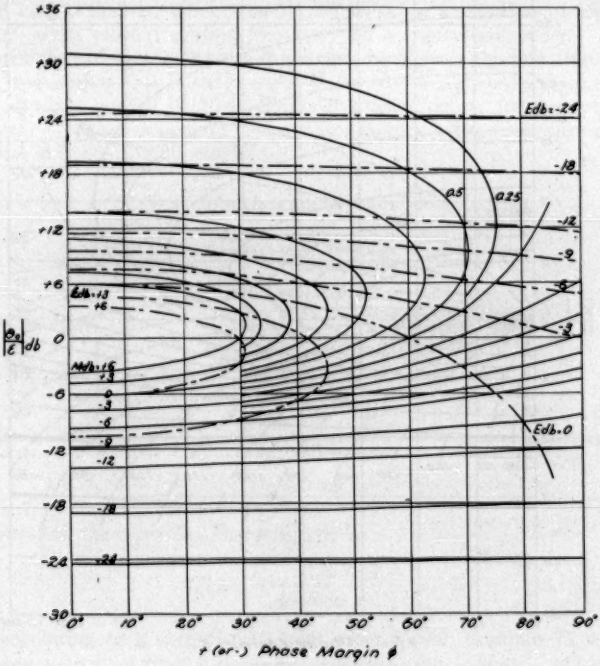

FIG. 6. Contours of constant ratios of output to input.

———— $|\theta_o/\theta_i| = M$

— — — $|\epsilon/\theta_i| = E$

E-curves are reflections in the 0 db axis of the corresponding M-curves.) In Fig. 6(a) the M-curves are replotted, together with curves of constant phase shift ψ of output with respect to input, $\psi = \angle (\theta_o/\theta_i)$. The phase shift characteristic of the servo thus may be determined by superposing A on Fig. 6(a) and reading the intersections of the transformed Nyquist graph with the dashed-line curves.

If the Nyquist plane is the complex z-plane, then the above transformed plane is essentially the w-plane for the transformation $w = \log_e z = \ln z$. For if $z = r \exp(j\theta)$, $\ln z = \ln r + j\theta$. Since $\ln z$ is analytic, if rectangular coordinate scales in the w-plane were chosen such that

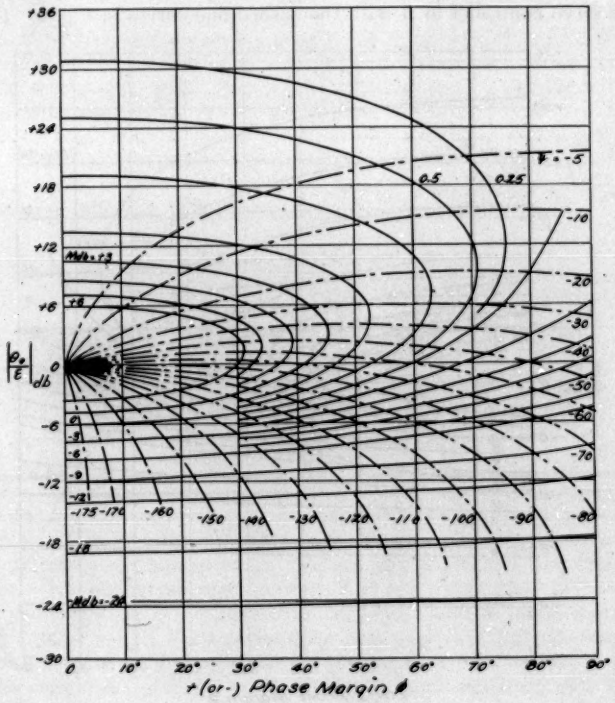

FIG. 6(a). Contours of constant ratio of output to input and of constant phase difference of output and input.

———— $|\theta_o/\theta_i| = M$

— — — — $\angle(\theta_o/\theta_i) = \psi$

(Each constant phase curve is labeled with the $(-)$ value of ψ in degrees, corresponding to positive ϕ. For negative ϕ, ψ is positive with the same numerical value.)

one radian and one neper (8.686 *db*) were equal units of distance, then angles would be preserved by the transformation. In particular, an orthogonal intersection of curves in the Nyquist z-plane would be transformed into an orthogonal intersection.

For controller characteristics of the rational form:

$$H(j\omega) = \frac{(T_1 j\omega + 1)(T_2 j\omega + 1)\cdots}{(Tj\omega)^n(S_1 j\omega + 1)(S_2 j\omega + 1)\cdots}$$

a fairly accurate sketch of the gain-phase margin diagram or transformed Nyquist diagram may be very rapidly obtained by first sketching the Bode chart, that is, the graph of $|H(j\omega)|_{db}$ as a function of $\log \omega$, or $|H(j\omega)|_{db}$ plotted against frequency on a logarithmic scale. The construction of such a chart is quite easy because of the fact that for high frequencies, each linear factor in $H(j\omega)$ is approximated very closely by a straight line, of slope $+6$ *db* per frequency octave for numerator factors, -6 *db* per octave for denominator factors. The procedure may be best indicated by an example.

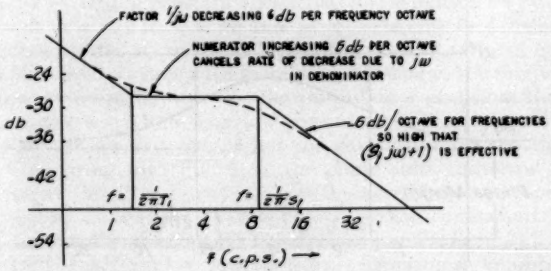

FIG. 7. Bode frequency-amplitude chart for controller characteristic.

Suppose the controller characteristic is:

$$H(j\omega) = \frac{T_1 j\omega + 1}{j\omega(S_1 j\omega + 1)},$$

corresponding to a zero-displacement error servo. Assume $T_1 > S_1$. At frequency $f = 1/(2\pi T_1)$, the numerator has a value $+3\ db = 20 \log\sqrt{2}$; at lower frequencies, the numerator contributes less than 3 *db* to $|H(j\omega)|_{db}$. Each time ω is doubled, the $j\omega$ in the denominator subtracts 6 *db* from $|H(j\omega)|_{db}$, since $6\ db = 20 \log 2$. Therefore, for frequencies up to $f = 1/(2\pi T_1)$, $|H(j\omega)|_{db}$ is approximately a straight line of slope -6 *db* per octave, as indicated in Fig. 7. For frequencies above $f = 1/(2\pi T_1)$, the factor $(T_1 j\omega + 1)$ approximately is equal to $T_1 j\omega$, and contributes $+6$ *db* per octave, cancelling the -6 *db* per octave contribution of $j\omega$ in the denominator; therefore, the graph of $|H(j\omega)|_{db}$ is approximately flat to the frequency $f = 1/(2\pi S_1)$ where the value of the factor $(S_1 j\omega + 1)$ in the denominator has increased to 3 *db*. Above this frequency,

$(S_1 j\omega + 1)$ contributes approximately -6 *db* per octave, so that as $f \to \infty$ the graph of $|H(j\omega)|_{db}$ is asymptotic to a straight line of slope -6 *db* per octave. The actual graph of $|H(j\omega)|_{db}$ everywhere differs from the asymptotic line approximation by less than 3 *db*, with maximum positive deviation near $f = 1/(2\pi T_1)$, and maximum negative deviation near $f = 1/(2\pi S_1)$.

The phase of $H(j\omega)$ also may easily be sketched approximately, as indicated in Fig. 8. Up to $f = 1/(2\pi T_1)$, the phase of $H(j\omega)$ is principally the $-90°$ of the factor $j\omega$ in the denominator (dashed line). From $f = 1/(2\pi T_1)$ to $f = 1/(2\pi S_1)$, the $-90°$ is cancelled by approximately $+90°$ due to $(T_1 j\omega + 1)$; and beyond $f = 1/(2\pi S_1)$ the phases of $(T_1 j\omega + 1)$ and $j\omega$ approximately cancel, so that the phase of $H(j\omega)$ is nearly equal to the phase $-90°$ of the factor $(S_1 j\omega + 1)$. From this the phase margin characteristic may easily be sketched, as indicated in Fig. 8.

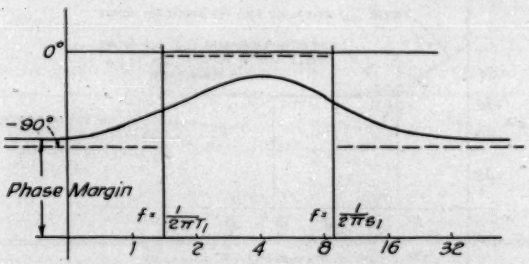

FIG. 8. Phase chart for controller characteristic.

Having the approximate frequency amplitude and frequency phase characteristics, corresponding values of $|H(j\omega)|_{db}$ and phase margin ϕ may be plotted in the *db*-phase margin plane, to obtain the transformed Nyquist diagram for the servo controller.

Since the phase margin for the above controller characteristic is always $\geqq 90°$, the servo will be stable no matter how high the gain setting k (equals velocity error constant k_v). (In an actual servo, other small time lag factors would be present in the denominator so that the gain could not be increased without limit with preservation of stability.)

If the numerator time lag T_1 were smaller instead of larger than the denominator time lag S_1, the phase margin would be less than 90° between $f = 1/(2\pi S_1)$ and $f = 1/(2\pi T_1)$, which would be a less favorable situation as regards stability of the servo. This case will be discussed in the third example of the next section.

3. EXAMPLES OF SERVO CONTROLLERS.

In order to obtain examples of gain-phase margin diagrams for servo controllers and their comparison with the M, E, and ψ curves to analyze

the servo performance, we shall consider several cases of the d-c. servo of Fig. 1. For simplicity, in all examples let us assume that the amplifier is an ideal amplifier with gain μ.

1. As a first example, suppose the motor is ideal or an exact integrator; that is, that its speed is proportional to the voltage V which is applied to the control field or armature, and suppose that the stabilizing network is omitted. For the controller in Fig. 1, we have then

$$\dot{\theta}_o = k_1 V = k_1 \mu \epsilon, \qquad p\theta_o = k\epsilon \qquad \text{where} \qquad k = k_1 \mu,$$

and the controller characteristic

$$\frac{\theta_o}{\epsilon} = \frac{k}{j\omega}.$$

The gain-phase margin diagram for this controller is the straight line $|H(j\omega)|_{db} = -|\omega|_{db}$ of constant (negative) phase margin 90°, extending from $+\infty$ *db* at $\omega = 0$ to $-\infty$ *db* at $\omega = \infty$. As may be determined by comparison with the M-curves in Fig. 6, the ratio $|\theta_o/\theta_i|_{db}$ of output to input amplitudes decreases with increasing frequency, starting with 0 *db* at $\omega = 0$. At frequency $\omega = k$, the output is 3 *db* below the input. Thus the entire servo acts as a low-pass filter or band-pass filter with center at zero frequency; the higher the gain k, the greater the bandwidth. Comparing with Fig. 6(*a*), the phase shift and error are seen to be 0 (error in $db = -\infty$) at $\omega = 0$, increasing to, respectively, 45° and -3 *db* at $\omega = k$. In this case it is also convenient to solve directly for $(\theta_o/\theta_i) = kH(j\omega)/[1 + kH(j\omega)] = k/(j\omega + k)$, and for $(\epsilon/\theta_i) = 1/[1 + kH(j\omega)] = j\omega/(j\omega + k)$. From these we obtain

$$\left|\frac{\theta_o}{\theta_i}\right| = \frac{k}{\sqrt{\omega^2 + k^2}}, \qquad \angle \frac{\theta_o}{\theta_i} = \arctan \frac{\omega}{k}, \qquad \left|\frac{\epsilon}{\theta_i}\right| = \frac{\omega}{\sqrt{\omega^2 + k^2}}.$$

2. Suppose that the differential equation of the motor is

$$T\dot{\theta}_o + \theta_o = k_1 V, \qquad T = J/f$$

where J is the moment of inertia of the armature and load, f is the viscous damping coefficient. Suppose again that the stabilizing network is omitted. Substituting $V = \mu\epsilon$ and taking transforms, we have

$$(Tp + 1)p\theta_o = k\epsilon$$

so that the controller characteristic is:

$$\frac{\theta_o}{\epsilon} = \frac{k}{j\omega(Tj\omega + 1)}.$$

The straight-line approximation to the controller amplitude characteristic in the Bode chart has a slope of -6 *db* per octave for frequencies up to $\omega = 1/T$; above this frequency the slope is -12 *db* per octave. The

phase margin is approximately 90° (270° due to $1/j\omega$ minus 180°) up to $\omega = 1/T$, and approximately 0° at frequencies above $\omega = 1/T$. The gain phase-margin diagram is curve (*a*) in Fig. 9, for the case of motor time constant $T = 0.2$ sec. For a peak $M = |\theta_o/\theta_i|$ not exceeding 2.0,

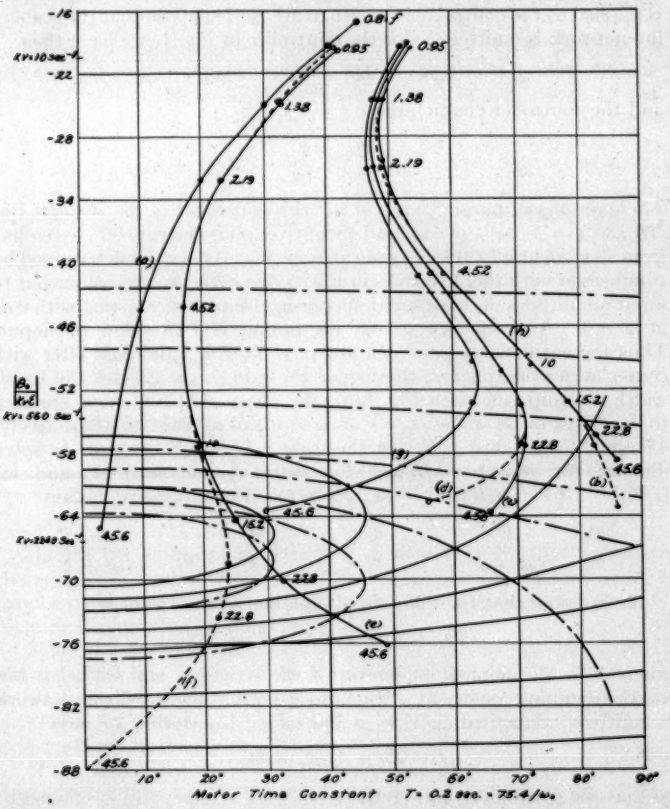

FIG. 9. (*a*) Proportional controller; (*b*) Ideal proportional-derivative characteristic; (*c*) True proportional-derivative characteristic with a time lag; (*d*) Approximate proportional-derivative characteristic obtainable with a parallel "T"; (*e*) 50-cycle parallel "T" with 60-cycle carrier frequency; (*f*) 70-cycle parallel "T" with 60-cycle carrier frequency; (*g*) Ideal proportional-derivative characteristic with 100° phase lag network (equal roots); (*h*) Ideal proportional-derivative characteristic with 90° phase lag. In (*b*) through (*h*), $T\omega_0 = 15$, and in (*c*) through (*f*) the time lag $= 0.5/\omega_0$.

due to the presence of the time lag factor $(Tj\omega + 1)$ in the denominator, the gain or velocity constant $k = k_v$ cannot be increased beyond approximately 10 sec.$^{-1}$. For $k_v = 10$ sec.$^{-1}$, the peak value is attained at a frequency in the vicinity of 1 cps.

3. Suppose the controller is as in (2), except that the stabilizing network is an ideal proportional-derivative network, that is a network with characteristic such that for an input voltage proportional to ϵ, the output is $k_2(\epsilon + T_d\dot{\epsilon})$, where T_d is the "derivative time constant." The controller characteristic is:

$$\frac{\theta_o}{\epsilon} = \frac{k(T_d j\omega + 1)}{j\omega(Tj\omega + 1)}.$$

For $T_d > T$, this characteristic has been discussed at the end of the last section ($S_1 = T$, $T_1 = T_d$). For $T_d < T$, specifically for $T = 0.2$ sec., $T_d = 15/377$ sec., the gain-phase margin diagram is curve (b) in Fig. 9.

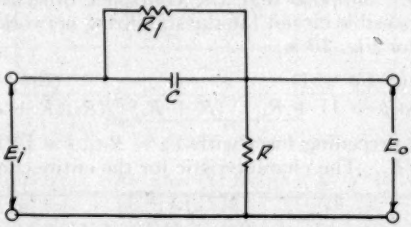

FIG. 10. A d-c. proportional-derivative stabilizing network.

Increasing the value of T_d improves stability and diminishes error, that is, improves fidelity, in the above ideal case. After the next example it will be clear, however, that in the case of an actual proportional-derivative characteristic, where a time lag factor is present in the denominator, although increasing T_d increases phase margin at the lower frequencies, it increases $|\theta_o/k_v\epsilon|_{db}$ at higher frequencies, with the effect that the value of $|\theta_o/k_v\epsilon|$ is large at a high frequency where the phase margin has decreased to a very small value, so that, for a prescribed degree of stability, the highest value of k_v which is possible with a high value of T_d is much lower than the k_v which is possible with a medium value of T_d. Figure 12 is a sketch illustrating this situation.

4. Suppose that the stabilizing network is an actual proportional-derivative network having a transfer characteristic of the form:

$$\frac{1}{n}\frac{(T_d j\omega + 1)}{(lj\omega + 1)}$$

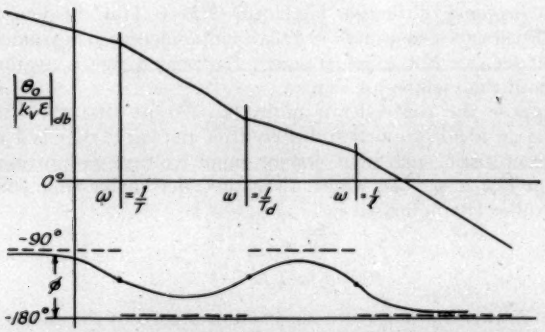

FIG. 11. Bode chart and phase characteristic for proportional-derivative controller (including time lag).

where $T_d = nl$. Suppose that the controller otherwise is as in (2). Figure 10 is a possible circuit for the stabilizing network. The transfer characteristic for Fig. 10 is:

$$\frac{E_o}{E_i} = \frac{R(R_1Cp + 1)}{R(R_1Cp + 1) + R_1} = \frac{R}{(R + R_1)} \frac{(R_1Cp + 1)}{[RR_1/(R + R_1)]Cp + 1}$$

which is of the preceding form with $T_d = R_1C$, $l = [RR_1/(R + R_1)]C$, $n = (R + R_1)/R$. The characteristic for the entire controller is

$$\frac{\theta_o}{\epsilon} = \frac{k(T_d j\omega + 1)}{j\omega(Tj\omega + 1)(lj\omega + 1)}.$$

The Bode chart and the graph of phase margin against frequency in octaves are of the nature indicated in Fig. 11. For the case of motor time constant $T = 0.2$ sec., $T_d = 15/377$ sec., $l = 0.5/377$ sec., the gain-phase margin diagram is curve (c) in Fig. 9.

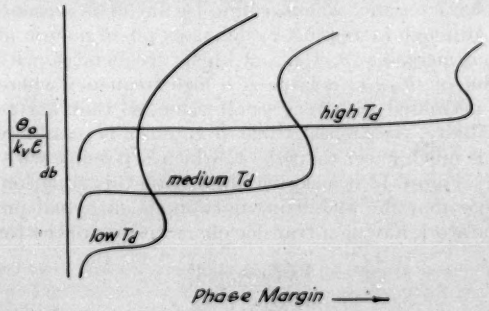

FIG. 12. Gain-phase margin diagrams for high, medium, and low values of T_d.

The general effect of varying T_d on the gain-phase margin diagram is depicted in the sketch of Fig. 12. For the preceding values of motor constant T and lag l, the value $T_d = 15/377$ sec. is an appropriate medium value.

4. OUTPUT OF A LINEAR CHARACTERISTIC FOR SUPPRESSED-CARRIER MODULATED INPUT.

In order to analyze the a-c. servomechanism of Fig. 2, it is necessary to calculate the effect of a linear transfer characteristic on a suppressed-carrier modulated voltage.[3] [Compare below with (2), p. 248.]

Let $G(j\omega)$, Fig. 13, be any linear transfer characteristic, defined for positive frequencies. This means that for a real input $\cos \omega t$, the output is $R[G(j\omega) \exp(j\omega t)]$, and for a real input $\sin \omega t$, the output is $I[G(j\omega) \times \exp(j\omega t)]$. Suppose the modulation of the suppressed-carrier modulated input is sinusoidal, with angular frequency m; let the input be of the form $\cos mt \cos \omega_0 t$.

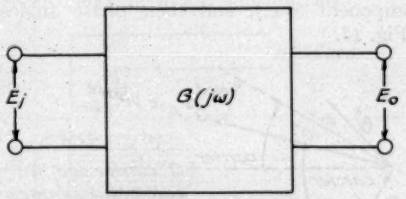

FIG. 13. A transfer characteristic.

By a formula of elementary trigonometry, the input may be written in the form:

$$E_i = \cos mt \cos \omega_0 t = \tfrac{1}{2}[\cos (\omega_0 + m)t + \cos (\omega_0 - m)t].$$

The output is:

$$\begin{aligned} E_o &= \tfrac{1}{2}R\{G[j(\omega_0 + m)]e^{j(\omega_0+m)t} + G[J(\omega_0 - m)]e^{j(\omega_0-m)t}\} \\ &= \tfrac{1}{2}\{|G[j(\omega_0 + m)]|\cos[(\omega_0 + m)t + \phi] \\ &\quad + |G[j(\omega_0 - m)]|\cos[(\omega_0 - m)t + \psi]\} \end{aligned}$$

where $\phi = \angle G[j(\omega_0 + m)]$, $\psi = \angle G[j(\omega_0 - m)]$. This may be expanded in the form $E_o = \tfrac{1}{2}|G[j(\omega_0 + m)]|\{\cos (mt + \phi_1) \cos (\omega_0 t + \phi_2) - \sin (mt + \phi_1) \sin (\omega_0 t + \phi_2)\} + \tfrac{1}{2}|G[j(\omega_0 - m)]|\{\cos (mt + \psi_1) \times \cos (\omega_0 t + \psi_2) + \sin (mt + \psi_1) \sin (\omega_0 t + \psi_2)\}$ where $\phi_1, \phi_2, \psi_1, \psi_2$ are arbitrary angles such that $\phi_1 + \phi_2 = \phi, \psi_2 - \psi_1 = \psi$. We take $\psi_1 = \phi_1$, $\psi_2 = \phi_2$ to obtain the form $E_o = \tfrac{1}{2}\{|G[j(\omega_0 - m)]| + |G[j(\omega_0 + m)]|\}$

[3] In the a-c. servo, the error-signal is suppressed-carrier modulated since it is of the form $k\epsilon(t) \cos \omega_0 t$, where the modulation envelope $k\epsilon(t)$ is proportional to the servo error $\epsilon(t) = \theta_i(t) - \theta_o(t)$. An ordinary amplitude modulated signal would be of the form $[1 + k\epsilon(t)] \cos \omega_0 t$, where k would be the modulation index. In the previous form, the carrier component $\cos \omega_0 t$ is not present.

$\times \cos(mt + \phi_1)\cos(\omega_0 t + \phi_2) + \frac{1}{2}\{|G[j(\omega_0 - m)]| - |G[j(\omega_0 + m)]|\}$ $\times \sin(mt + \phi_1)\sin(\omega_0 t + \phi_2)$, $\phi_1 = \frac{1}{2}(\phi - \psi)$, $\phi_2 = \frac{1}{2}(\phi + \psi)$, which is a resolution into a main component and a quadrature component having the minimum possible amplitude.

The amplitude of the main component is the average of the amplitudes $|G^+|$ and $|G^-|$ of the upper and lower sidebands; the phase of the carrier is the average of the phases of the respective sidebands, while the modulation phase is one half the difference. The amplitude of the quadrature component is one half the difference of the amplitudes of the lower and upper sidebands; if $|G^-| > |G^+|$ the quadrature component lags the main component, and the carrier and modulation phases of the quadrature component lag those of the main component by 90°. The relationships between the sidebands, main component (m.c.), quadrature component (q.c.), and their phase angles, are indicated vectorially in Fig. 14.

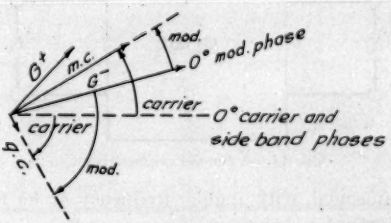

FIG. 14. Vector diagram for main and quadrature components.

Evidently if the amplitude characteristic of the linear system $G(p)$ is symmetrical about the carrier frequency, $|G[j(\omega_0 - m)]| = |G[j(\omega_0 + m)]|$, the quadrature component disappears, and the effect of $G(p)$ is similar to the effect of a d-c. system on the modulation, with a phase shift ϕ_2 of the carrier. In this form, the phase shift ϕ_2 may vary with the modulating frequency; if desired a different resolution may be made with a constant carrier phase shift angle in the main component.

5. EQUATION FOR TWO-PHASE MOTOR; DEMODULATOR CHARACTERISTICS.

A two-phase motor like the one used in the a-c. servo of Fig. 2 is depicted in Fig. 15. Suppose that $H_x = X\cos\omega_0 t$, X = constant, is the voltage applied to the fixed winding, and that $H_y = X\beta(t)$ is the voltage applied to the control winding. The differential equation relating the output θ_o of the motor and the input voltage $\beta(t)$ has been derived by N. B. Nichols; it is

$$T\ddot{\theta}_o + [1 + \cos 2\omega_0 t + 2\beta^2(t)]\dot{\theta}_o = 2\omega_0\beta(t)\sin\omega_0 t + 2\dot{\beta}(t)\cos\omega_0 t$$

where T is a time constant associated with the motor and the load on the output. (In the derivation of this equation, the effect of circulating rotor currents on the stator field was neglected.)

For small amplitudes of the input $\beta(t)$, if the high-frequency term $\cos 2\omega_0 t$ is neglected, the above equation simplifies to the linear equation

$$T\ddot{\theta}_o + \dot{\theta}_o = 2\omega_0\beta(t) \sin \omega_0 t + 2\dot{\beta}(t) \cos \omega_0 t.$$

If $\beta(t) = \beta_1 \sin \omega_0 t$ [$\beta(t)$ then is 90° out of phase with the fixed winding excitation], the motor will run at constant speed $2\omega_0\beta_1$. If $\beta(t) = \beta_1 \times \sin(\omega_0 t + \theta)$, the right-hand side of the differential equation is $2\omega_0\beta_1[\sin \omega_0 t \sin(\omega_0 t + \theta) + \cos \omega_0 t \cos(\omega_0 t + \theta)] = 2\omega_0\beta_1 \cos\theta[\sin^2 \omega_0 t + \cos^2 \omega_0 t] = 2\omega_0\beta_1 \cos\theta$, so that the motor will run at constant speed $2\omega_0\beta_1 \cos\theta$. If $\theta = \pi/2$, then $\beta(t) = \beta_1 \sin(\omega_0 t + \pi/2) = \beta_1 \cos \omega_0 t$, the right-hand side is zero, and the motor will not run.

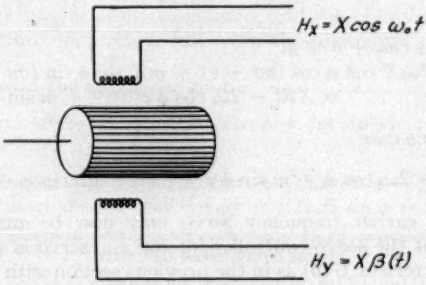

FIG. 15. Two-phase motor.

If the voltage applied to the fixed winding is $H_x = X \sin(\omega_0 t + \phi)$ instead of $X \cos \omega_0 t$, then by a change of origin of time t, the simplified differential equation of the motor becomes

$$T\ddot{\theta}_o + \dot{\theta}_o = -2\omega_0\beta(t) \cos(\omega_0 t + \phi_o) + 2\dot{\beta}(t) \sin(\omega_0 t + \phi_o).$$

For a control voltage input $\beta(t) = \cos(mt + \theta) \cos(\omega_0 t + \phi_o)$, the right-hand side of the differential equation is:

$$-2\omega_0 \cos(mt + \theta) \cos^2(\omega_0 t + \phi_o) - m \sin(mt + \theta) \sin 2(\omega_0 t + \phi_o) - 2\omega_0 \cos(mt + \theta) \sin^2(\omega_0 t + \phi_o) = -2\omega_0 \cos(mt + \theta),$$

on neglecting the high frequency term. For a control voltage input $\beta(t) = \cos(mt + \theta) \sin(\omega_0 t + \phi_o)$, the right-hand side is:

$$-2\omega_0 \cos(mt + \theta) \sin(\omega_0 t + \phi_o) \cos(\omega_0 t + \phi_o) - 2m \sin(mt + \theta) \sin^2(\omega_0 t + \phi_o) + 2\omega_0 \cos(mt + \theta) \sin(\omega_0 t + \phi_o) \cos(\omega_0 t + \phi_o) = -m \sin(mt + \theta)$$

on substituting $\sin^2(\omega_0 t + \phi_o) = (1 - \cos 2\omega_0 t)/2$ and neglecting the high frequency term. (The assumed justification for neglecting the high frequency terms is that their average or macroscopic effect is zero.)

For a control voltage input $\beta(t) = \cos(mt + \theta)\cos(\omega_0 t + \phi_o + \phi) = \cos(mt + \theta)[\cos(\omega_0 t + \phi_o)\cos\phi - \sin(\omega_0 t + \phi_o)\sin\phi]$, by the preceding paragraph, the right-hand side is:

$$\cos\phi[-2\omega_0 \cos(mt + \theta)] = \sin\phi[-m\sin(mt + \theta)].$$

Thus the a-c. motor is effectively equivalent to a demodulating device followed by a d-c. motor.

The general linear demodulator characteristic would be that for an input $\beta(t) = X\cos(mt + \theta)\cos(\omega_0 t + \phi_o + \phi)$, the output is $|P(\phi, m)|X \times \cos(mt + \theta + \rho)$, where $\rho = \angle P(\phi, m)$. In the above case of the right-hand side of the differential equation of the two-phase motor, the output is:

$$\begin{aligned}|P(\phi, m)|X\cos(mt + \theta + \rho) &= -2\omega_0 X\cos\phi\cos(mt + \theta) + mX\sin\phi\sin(mt + \theta)\\ &= XR[-2\omega_0\cos\phi\, e^{j(mt+\theta)} + m\sin\phi\, e^{j(mt+\theta-\pi/2)}].\end{aligned}$$

Therefore in this case

$$P(\phi, m) = -2\omega_0\cos\phi + m\sin\phi\, e^{-j\pi/2} = -2\omega_0\cos\phi - jm\sin\phi.$$

Any linear carrier frequency servo may now be analyzed. The characteristic of the servo controller for the a-c. servo is the combination of a characteristic $G(p)$ as in the previous section with the demodulator and motor characteristics. The output of $G(p)$ is applied to the control winding of the motor (or more generally the output of $G(p)$ is applied to a demodulator characteristic $P(\phi, m)$ and the demodulated output is applied to the motor). As in the previous section, if the input to $G(p)$ is $\epsilon_1\cos mt\cos\omega_0 t$, that is $\epsilon = \epsilon_1\cos mt$, the output is

$$\begin{aligned}E_o = \epsilon_1[&A(m)\cos(mt + \phi_1)\cos(\omega_0 t + \phi_o + \phi)\\ &+ B(m)\sin(mt + \phi_1)\sin(\omega_0 t + \phi_o + \phi)]\end{aligned}$$

where

$$\begin{gathered}A(m) = (|G^-| + |G^+|)/2 = (|G[j(\omega_0 - m)]| + |G[j(\omega_0 + m)]|)/2,\\ B(m) = (|G^-| - |G^+|)/2, \quad \phi^+ = \angle G^+, \quad \phi^- = \angle G^-,\\ \phi_1 = (\phi^+ - \phi^-)/2, \quad \phi = -\phi_o + (\phi^+ + \phi^-)/2, \quad \phi_o = \angle G(j\omega_0).\end{gathered}$$

For an input:

$$\begin{aligned}\beta(t) = A\cos(mt + \phi_1)\cos(\omega_0 t + \phi_o + \phi)\\ + B\cos(mt + \phi_1 - \pi/2)\cos(\omega_0 t + \phi_o + \phi - \pi/2)\end{aligned}$$

to the demodulator characteristic $P(\phi, m)$, the demodulator output (right-hand side of the motor differential equation) is:

$$\begin{aligned}&|P(\phi, m)|A\cos(mt+\phi_1+\rho_1)\\&\quad+|P[(\phi-\pi/2), m]|B\cos(mt+\phi_1+\rho_2-\pi/2)\\&\quad=R\{[P(\phi, m)Ae^{j\phi_1}+P[(\phi-\pi/2), m]Be^{j(\phi_1-\pi/2)}]e^{jmt}\}\\&\qquad\qquad=|Q(m)|\cos(mt+\tau),\\&Q(m)=P(\phi, m)Ae^{j\phi_1}+P[(\phi-\pi/2), m]Be^{j(\phi_1-\pi/2)},\end{aligned}$$

$\tau = \angle Q(m)$. (The quantities ϕ, ϕ_1, A, B depend on m through $G(p)$.) The linear characteristic $Q(m)$ is the over-all characteristic of the portion of the servo controller including $G(p)$ and the demodulator; for an error $\epsilon = \cos mt$, the differential equation of the motor is:

$$T\ddot{\theta}_o+\dot{\theta}_o=|Q(m)|\cos(mt+\tau), \quad \tau=\angle Q(m).$$

Thus the servo controller characteristic is $\theta_o/\epsilon = Q(m)/(-Tm^2+jm)$. From this θ_o/ϵ may be easily calculated, and the Nyquist or gain-phase margin diagram constructed, following the procedure outlined in the next section.

In the case of the two-phase motor,

$$P(\phi, m)=-(2\omega_0\cos\phi+jm\sin\phi),$$

and

$$\begin{aligned}Q(m)&=-(2\omega_0\cos\phi+jm\sin\phi)Ae^{j\phi_1}+j(2\omega_0\sin\phi-jm\cos\phi)Be^{j\phi_1}\\&=[(-2\omega_0A\cos\phi+mB\cos\phi)+j(2\omega_0B\sin\phi-mA\sin\phi)]e^{j\phi_1}.\end{aligned}$$

6. CONSTRUCTION OF GAIN-PHASE MARGIN DIAGRAM FOR ANY $G(p)$ WITH TWO-PHASE SERVO MOTOR.

From the servo controller characteristic and calculation of $Q(m)$ in the preceding section, the angle of $\theta_o/k_v\epsilon$ evidently is:

$$\angle\frac{\theta_o}{\epsilon}=\phi_1+\alpha-90^\circ-\arctan mT$$

where

$$\tan\alpha=-\frac{[2\omega_0B(m)-mA(m)]\sin\phi}{[2\omega_0A(m)-mB(m)]\cos\phi}.$$

Thus we have:

$$\text{phase margin}=90^\circ+\phi_1+\alpha-\arctan mT.$$

By a preceding discussion, the reciprocal of the error for a step-velocity input is the velocity error constant

$$\begin{aligned}k_v&=\lim_{m\to0}jm(\theta_o/\epsilon+1)=\lim_{m\to0}[Q(m)/(Tjm+1)+jm]\\&=Q(0)=-2\omega_0A(0)=-2\omega_0|G(j\omega_0)|.[4]\end{aligned}$$

[4] The minus sign means that actually the servo corresponding to the two-phase motor demodulator characteristic $P(\phi, m)$ is unstable; for stable operation the connections to the control winding of the motor would merely be reversed, so that the demodulator characteristic would be $-P(\phi, m)$. Or in the case of synchros, the normal position of the output shaft would rotate 180° with respect to the input shaft, reversing the sign of the error.

Therefore, we have also:

$$\left|\frac{\theta_o}{k_v\epsilon}\right| = \frac{\{[2\omega_0 A(m) - mB(m)]^2 \cos^2\phi + [2\omega_0 B(m) - mA(m)]^2 \sin^2\phi\}^{\frac{1}{2}}}{2\omega_0 |G(j\omega_0)|\,|m(1+m^2T^2)^{\frac{1}{2}}} = \frac{[2\omega_0 A(m) - mB(m)]\cos\phi\cos(\arctan mT)}{2m\omega_0 |G(j\omega_0)|\cos\alpha}.$$

In proceeding with the calculation of the required numerical values for the construction of the gain-phase margin diagram, it is convenient to read arc tan x and cos (arc tan x) $= 1/(1+x^2)^{\frac{1}{2}}$ simultaneously from a table of natural trigonometric functions. A tabular procedure is recommended for obtaining the values of phase margin and corresponding ratios $|\theta_o/k_v\epsilon|$. For successive values of modulating frequency m, find and enter in the table: ϕ^+, ϕ^-, ϕ, $\cos\phi$, $|G^-|$, $|G^+|$, $A(m)$, $B(m)$, $[2\omega_0 A(m) - mB(m)]$, $\tan\alpha$, $\cos\alpha$ from $G(p)$, mT, cos (arc tan mT) from the motor time constant T, then finally phase margin, ratio $|k_v\epsilon/\theta_o|$, and $|\theta_o/k_v\epsilon|$ in $db = -|k_v\epsilon/\theta_o|$ in db.

For a carrier frequency of 60 cycles, that is $\omega_0 = 2\pi 60 = 377$, Table I, used in the construction of the gain-phase margin diagrams in

TABLE I.

arc tan mT	mT	$(1+m^2T^2)^{-1/2}$ $= \cos$ (arc tan mT)	m for $T = 0.2$ sec.	$\frac{m}{2\pi}$ in cps.	$\frac{2\omega_0 - m}{2(\omega_0 - m)}$	$\frac{2\omega_0 + m}{2(\omega_0 + m)}$	$\frac{11}{6}\frac{\omega_0 - m}{2(\omega_0 - m)}$	$\frac{11}{6}\frac{\omega_0 + m}{2(\omega_0 + m)}$	$\frac{13}{6}\frac{\omega_0 - m}{2(\omega_0 - m)}$	$\frac{13}{6}\frac{\omega_0 + m}{2(\omega_0 + m)}$	$\frac{\omega_0 - m}{\omega_0}$	$\frac{\omega_0 + m}{\omega_0}$	arc tan $\frac{15}{\omega_0}\frac{m}{}$	cos $\left(\text{arc tan } \frac{15}{\omega_0}\frac{m}{}\right)$
50°	1.192	0.643	5.96	0.95	1.008	0.992	0.924	0.910	1.093	1.074	0.985	1.015	13.3°	0.973
60°	1.732	0.500	8.66	1.38	1.012	0.989	0.925	0.909	1.097	1.070	0.978	1.022	19.0°	0.9455
70°	2.75	0.342	13.75	2.19	1.019	0.982	0.933	0.902	1.105	1.063	0.963	1.036	28.65°	0.8775
80°	5.67	0.1736	28.35	4.52	1.041	0.965	0.951	0.886	1.131	1.043	0.925	1.075	48.4°	0.664
85°	12.56	0.0794	62.8	10.0	1.100	0.929	1.00	0.857	1.200	1.000	0.835	1.167	68.2°	0.3714
87°	19.08	0.0523	95.4	15.2	1.169	0.899	1.06	0.832	1.281	0.966	0.741	1.252	75.2°	0.255
88°	28.64	0.0349	148.3	22.8	1.324	0.859	1.16	0.806	1.462	0.919	0.607	1.392	80.4°	0.167
89°	57.29	0.0175	286.5	45.6	2.583	0.784	2.23	0.737	2.930	0.831	0.240	1.76	85°	0.0872

the next section, will be useful to the reader in constructing diagrams for any additional cases of $G(p)$ and $P(\phi, m)$ in which he may be interested.

7. PROPORTIONAL-DERIVATIVE FREQUENCY-PHASE CHARACTERISTICS.

The ideal proportional-derivative stabilizing characteristic for a carrier frequency servo is $G(j\omega) = 1 + jT_d(\omega - \omega_0)$. It may be shown that if a modulated carrier voltage $m(t)\cos\omega_0 t$ is impressed on this characteristic, the output is $[m(t) + T_d\dot{m}(t)]\cdot\cos\omega_0 t$. The ratio T_d of the coefficients of the differentiated and proportional components is called the "derivative time constant."

A parallel "T" network (Fig. 16) may be used in $G(p)$ to obtain an approximation to the ideal proportional-derivative characteristic. Part II of this paper will be concerned with the design of parallel "T" networks for this purpose (and with the allowable tolerances in the values of the R and C components).

The approximation to the ideal proportional-derivative characteristic which it is possible to obtain with the parallel "T" network is

$$G(j\omega) = \frac{l}{T_d} \frac{1 + jT_d \dfrac{\omega + \omega_0}{2\omega} (\omega - \omega_0)}{1 + jl \dfrac{\omega + \omega_0}{2\omega} (\omega - \omega_0)} \tag{7-1}$$

where the time lag l cannot be larger than $1/\omega_0$.

It has been found experimentally that different servo setups require different values of T_d for best stability; however T_d is not at all critical. Values of $T_d\omega_0$ in the range of 5 to 50 have been found useful.

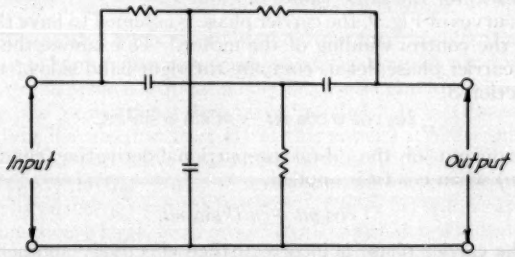

FIG. 16. Parallel "T" network.

As mentioned in section 3, curve (a) in Fig. 9 is the gain-phase margin diagram for a simple proportional controller, that is, a controller in which $G(p)$ is identically 1 or a constant, so that the controller characteristic $H(p)$ is the motor characteristic $1/(Tp + 1)p$. Comparing with Fig. 6, evidently even with low gains (k, in the vicinity of 10 sec.$^{-1}$), there are peaks of large amplitude at low frequencies. In an actual servo system, where there are time lags not included in curve (a) (as for example a small time lag in the coupling circuits between stages of a vacuum tube amplifier), as the gain is increased, the servo output quickly will begin to oscillate violently and continuously, with no input; that is, the servo will be unstable.

Curve (b) in Fig. 9 is the corresponding plot for the servo controller consisting of the ideal proportional-derivative characteristic with $T_d\omega_0 = 15$, and the simplified motor of section 5, with $T = 0.2$ sec. This value of T is approximately the value for the Diehl FPE-49-2

motor. Comparing with Fig. 6, evidently the servo now is very stable at all values of k_v. That is, if $k_v = 560$ sec.$^{-1} \sim 55$ *db*, the frequency response $|\theta_o/\theta_i|$ is nearly flat from 0 to 20 cps. or higher, and the output θ_o of the servo is a very faithful copy of the input θ_i, even though θ_i may be of such a nature as to have components of rather high frequency. In particular the output for a step displacement of the input θ_i will also be very nearly a step, and will have no overshoot. This is unlike the situation for the proportional servo (with the same velocity error constant), where for a step input the output has many overshoots and only gradually settles down to the displacement corresponding to the input displacement.

Curve (*c*) is the decibel-phase margin plot for the proportional-derivative characteristic $G(j\omega) = \dfrac{1+jT_d(\omega-\omega_0)}{1+jl(\omega-\omega_0)}$ with time lag $l = 0.5/\omega_0$, and $T_d\omega_0 = 15$. Curve (*d*) is the plot for the approximate proportional-derivative characteristic (7-1), which may be obtained with the parallel "*T*" network, for the same values of l and T_d.

In all curves of Fig. 9, the carrier phase is assumed to have the proper value for the control winding of the motor. To examine the effect of incorrect carrier phase, let us compare the right-hand side of the equation in section 5,

$$2\omega_0 \cos\phi \cos mt - m \sin\phi \sin mt,$$

with the output of the (d-c.) proportional-derivative characteristic $(1 + Ujm)$ when $\cos mt$ is applied,

$$\cos mt - mU \sin mt.$$

Thus if the carrier phase is incorrect, then effectively another proportional-derivative characteristic $(1 \pm Ujm)$ is in cascade with the stabilizing characteristic $(1 + T_d jm)$, with $U = \tan\phi/2\omega_0$. The gain is reduced by the factor $\cos\phi$, although the actual voltage on the motor (and its heating effect) is not reduced. Also the maximum available torque of the motor, that is, the torque at saturation, is reduced by the factor $\cos\phi$. If gain and maximum torque reduction by a factor of 0.5 is tolerable, then as much as 60° phase shift may be allowed, since $\cos 60° = 0.5$. For errors ϕ in carrier phase up to 45° or 60°, $U\omega_0$ is less than 0.5 or 0.87, so for $T_d\omega_0 > 5$, the effect on stability of $(1 \pm Ujm)$ is comparatively quite insignificant.

The high values of k_v attainable with the parallel "T," and the flat frequency characteristic, have been verified experimentally in a servo setup using 5*G* synchros and the Diehl FPE-49-2 motor. (We had $k_v = 5000$ sec.$^{-1}$ with satisfactory freedom from chatter; the only limitation on k_v seems to be backlash in the gear train.)

Curves (*e*) and (*f*) in Fig. 9 are decibel-phase margin plots for the servo controller consisting of the motor of section 5, and the parallel

"T" approximate proportional-derivative characteristic, the characteristic however being tuned to frequencies $\omega_1 = 2\pi 70$ and $\omega_1 = 2\pi 50$, instead of to the carrier frequency $\omega_0 = 2\pi 60$. There is then respectively a phase lag of 64.5°, or a phase lead of 62.1°, at carrier frequency ω_0. Including this phase shift, the phase of the carrier at the control winding of the motor is assumed to be correct (if not, the previous remark on the small effect of incorrect carrier phase still applies, and for phase errors up to 65° the stability is not appreciably different from that indicated by curves (*e*) and (*f*)). It is evident from the diagrams that when the parallel "T" network is tuned to a frequency as much as 10 cycles *lower* than the 60-cycle carrier, the stability still is very satisfactory at high values of k_v. However, when the parallel "T" network is tuned to a frequency 10 cycles *higher* than the 60-cycle carrier, even with the optimal setting of k_v (about 3000 sec.$^{-1}$), there will be a peak in the region of 15 to 25 cps. of height greater than 2. (For deviations of ±8 cycles, these conclusions also have been verified experimentally.)

8. EFFECT OF PHASE-LAG NETWORKS ON STABILITY.

Experimentally, it has been found satisfactory to shift the phase of the carrier to obtain the proper phase at the control winding, by inserting into the servo controller a one- or two-section low pass *R-C* filter preceding the proportional-derivative parallel "T." (Phase-lag networks will be discussed in Part III of this paper.) When this is done, the proportional-derivative characteristic is multiplied by $1/(Up + 1)$ or by $1/(U_1p + 1)(U_2p + 1)$. The effect on stability to be expected is indicated by curves (*g*) and (*h*) in Fig. 9. Curve (*h*) will be approached as U becomes very large, or as one of U_1, U_2 approaches infinity and the other approaches zero. Curves (*g*) and (*h*) indicate, for a two-section filter to obtain say 100° phase lag, that better results, as regards keeping the amplification of noise or jitter and backlash chatter small, will be obtained by having the roots U_1^{-1} and U_2^{-1} as unequal as possible, than by having them nearly equal. Also, the high rate of decrease of phase margin with respect to error frequency in the range 15 to 45 cps., in combination with other time lags in the system not included in curve (*g*), may help to explain an observed tendency of the servos to oscillation at the subharmonic frequency of 30 cps.

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Radioactive Chemical Precautions.—In experimenting with radioactive chemicals from the atomic piles at Oak Ridge, plant scientists of the U. S. Department of Agriculture have stopped using the familiar clay pots and jars in their greenhouse experiments. Instead they are using inexpensive tin cans coated with enamel. After each experiment they discard the cans and soil that contains the radioactive material, and bury them deep in the ground to get rid of them.

The reason is simple. In checking the action of the radioactive chemicals moving out of the soil and into and through the plant, the scientists make use of the delicate "tracer" method. Counting instruments detect and record the passage of charged molecules as they pass through the plant tissues. It is necessary to have exact knowledge as to the radiant energy present at the start of the experiment. This is possible by using fresh soil, a new container, and and exactly measured quantities of radioactive chemicals. But if a clay container had been used previously, the pot would have become at least slightly radioactive, and so would add some unmeasured radioactive energy that would complicate the experiment. It would disturb what the scientists term the "control" of conditions.

R. H. O.

X-Ray Gage Controls Sheet Thickness.—In answer to the thickness gaging problems in modern high speed rolling mills, there has been developed an X-ray thickness gage offering unique advantages of (1) no contact with the material being gaged, (2) ready access to areas never before gaged, and (3) high sensitivity and accuracy.

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Present applications to sheet metals indicate that the gage will increase output of prime sheet, solve some operating problems, and eliminate marring of the surface of the materials being gaged. As a quality control instrument, this equipment is expected to find application in the thickness control of hot metal and glass sheet, aluminum foil, plastics, paper, and other sheet and strip materials.

Employing two X-ray sources at right angles with one photomultiplier-fluorescent screen pick-up unit at the apex, the gage compares the controlled material to a correct sample. The two X-ray sources emit X-rays 180° out of phase.

Positive and negative readings showing the thickness differential above or below the standard sample are shown on an instrument within view of the operator. The gage automatically rejects off-gage material in flying shear applications or controls the screw downs to maintain uniform thickness in material coming from a cold mill. One model now installed on a tinplate line is designed for thickness of sheet from 0.005 to 0.050 in., but the basic equipment is the same for other applications. The indicator needle on the gage instrument will react to a variation of 0.0001 in. in a 0.1-in. thick sheet.

It is unaffected by fluttering of the sheet, surface coatings such as lacquer, or by atmospheres heavy with palm oil, steam, and water. Normally mounted on a slide so that it can be removed from the pass line, it can also be arranged to rove across the sheet.

R. H. O.

THE FULL RESPONSIBILITY OF MANAGEMENT.*

BY

WILLIAM J. MEINEL.[1]

We are assembled here tonight to pay honor to Mr. Charles Day, who did much for business and industry as one of the outstanding pioneers in modern industrial management. He was a great engineer and leader in his field.

I think we should also pay honor to The Franklin Institute and its staff for the great job they are doing in research and development, for which they recently received a gold medal. They are aiding our government in improving its defense weapons in the interest of keeping America strong.

I have been asked to speak to you tonight on the subject of management in business and industry. I must confess that this embarrasses me, since many of you in this audience are better qualified to talk on this subject.

In discussing the responsibilities of management, it is my motive to impress upon you the importance of being modern, alert and everlastingly on the look-out for new business opportunities.

Keeping our factories and our products up-to-date; making every effort to be well informed; keeping abreast of the times, especially with respect to the many external influences which affect our business affairs; having the courage to accept new responsibilities; and taking time out for honest appraisal of ourselves and the effort which we are devoting to our jobs, are all required of good management and should be foremost among the policies of modern executives.

Wisdom in management also demands that modern executives have a definite program of training those who are to succeed them as leaders. Charlie Schwab, for example, selected Eugene Grace to serve his great institution when he no longer was able to carry the burden of management. He sensed that a younger man was required to plan for the future of that business. At the present time, Mr. Eugene Grace is training a younger man by the name of Homer to accept the full responsibility of top management in the Bethlehem organization.

Whenever possible, these future leaders should be chosen from among the young men in your organization.

They should be the men who have shown initiative and some capac-

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[1] President, Heintz Mfg. Co., Philadelphia, Pa.

ity to perform the lighter tasks of management, and who have the physical and mental vigor demanded of those in high executive positions. Our training programs should, if possible, follow a regular prescribed form, arranged so that nothing of importance is overlooked in the business education of these future executives. A well-thought-out plan for training our successors is the best insurance with which we can endow our company. It is the means by which we pass along to others a store of knowledge useful to the business long after we have retired from active participation. This is our contribution to the future.

Our responsibility to the present is a much more pressing matter. If we are to be regarded as good managers, we must find or create opportunities for the entire business to prosper, to progress, expand and improve.

It is only through constant improvement that we can maintain our position in the world's markets and so remain in business. If we fail to make improvements, we are certain to lose ground. We must advance, or go out of business as failures.

On this point I know that many of you take great pride in a particular product of your company, which you consider the last word in improvement and I have no doubt there is justification for your satisfaction.

My only suggestion is, do not become too complacent. Philco, Frigidaire, Buick, Ford, Dodge, Luckies, Camels, Wheaties and a host of other products have been made a part of our everyday lives by good businessmen with a plan of constant adherence to the policy of product improvement. Who would be so foolhardy as to insist that there has not been a profound improvement in these products? Even tobacco smokers receive an incredible amount of attention from the producers of smokers' requirements. Each year the makers of cigarettes spend millions of dollars to urge upon us the information that their products have been improved by being "moisturized," "toasted," "cooled," or by some betterment not found in competitive brands. The improvement which has been made in these products is undoubtedly the reason why they have retained their popularity for so many years. I think it goes without question that keeping up-to-date should be the first concern of good management.

While on this point, I should like to discuss another side of this problem of keeping abreast of the times.

In the past several years I have visited a large number of factories in the eastern part of the United States and I have found an almost unbelievable amount of neglect of the machinery, equipment, buildings and other facilities, upon which the very existence of some of these businesses depends. I have always been inclined to think the external appearance of a factory and the amount of attention paid to cleanli-

ness and maintenance is a good guide as to the calibre of management of a business.

Let me suggest that you include plant conservation in your keeping-up-to-date program. You will find it one of the most gratifying accomplishments of management for the reason that everyone associated with the business is visibly benefitted. Employees have a better place in which to work and as a result, the output of the plant is usually increased; the assets of the business are properly conserved; the appearance of the plant is improved to the point where our neighbors become proud of us (I shall have more to say on the subject of neighbors later in this message).

We have looked carefully at our products and our properties, so now let us take a careful scrutiny at ourselves.

What about our attitude toward our jobs? How much enthusiasm do we bring to the office every day? How many divisions of the business do we find genuinely interesting? How well informed are we in the case of those divisions of the business which we find a bit dull or commonplace? How much civic pride do we take in the community where our plant is located? These are only a few of the matters which test our talent as executives.

Enthusiasm for our jobs is usually reflected in those who work with and for us and is a tremendous factor in creating employee interest and loyalty. No other single factor is as important to good labor relations as a workingman's sound confidence in the managers of his company. Right here is what I consider the most important part of my message. The one way management can build confidence and earn the loyalty of its workingmen is to be on the job every day. The man who runs a lathe in the shop is always proud (and therefore gratified) to know the company executives. Let us not delude ourselves about the man who works for us. He is an intelligent human being and is quick to learn whether or not the management of his company is putting real effort into making a success of the enterprise. If he has assurance that the executives are going to be on the job every day, he learns to group himself with them as a team.

Therefore, if the executives are enthusiastic, then so is the remainder of the organization.

Contrast this situation with the case where there is absentee management, where a company maintains its home office in Philadelphia and its factory in Boston. No one among the workingmen ever sees the executives of his company, and too often the same thing applies to many of the supervisors of the factory. They, and the home office executives, are complete strangers.

I am about to make a statement which may surprise you. The management of big business is, in many cases, responsible for the numerous difficulties with which business is confronted in dealing with

today's labor. It would seem to me that there was every reason for businesses in America to expand their operations and increase their output, so that low-cost production could be made available to more people at prices within the range of their ability to pay. The automobile, refrigerator and many other necessities and luxuries would not be available to the average workingman if big business had not made the tremendous investment in tooling that was not possible on the part of the smaller company.

I am trying to point out to you that the merging of small business and the building up of large companies was fully justified. However, the employee no longer had the comfort of knowing top management. The executives believed that the appointment of a personnel manager would take care of the human relation problems that are so important to every business.

There is no doubt that the personnel manager has his rightful place. However, he cannot take the place of top management where the important business decisions are made, particularly those that affect the security of the workingman.

One other practice of big business that contributes some to our worker difficulties is the shifting of top management from one division of the business to another. Every time this is done, the entire organization is obliged to make a new start, and until the employees learn what new duties are assigned to them by the incoming manager, the operations of the branch are unsatisfactory.

Many of the lessons learned and policies established by the departing manager must be discovered anew by his successor.

If the departing manager had been actively interested in local civic matters, or had been highly regarded by his workers and the community as a whole, there is certain to be some antagonism toward his successor, who cannot possibly know how far he must go in filling the void created by the departure of his predecessor.

I know of one large company which was as much as 15 years ahead in its labor policy. This company pioneered collective bargaining. The Wagner Act made little or no change in their industrial relations setup, since they had followed the mandates of this Act for many years before it became a law. They had a very happy employee situation until they adopted a policy of shifting top management. The difficulties they have encountered over the past 5 or 6 years are, in my opinion, a direct outcome of the many changes they made in the managers of their various plants located in many cities throughout the country.

Another disturbing action of absentee management is the stopping or changing of production for reasons which are seldom made clear to the people who are most affected—the workers of the factory. Imagine the resentment that is created.

No other single action of management is as likely to cause the workers to follow a professional organizer (whether he presents a good union or a bad one, and whether he is capable of helping them, or is just an adroit twister of the truth).

This brings to mind a subject discussed at some length by Mr. Ralph Kelly when he addressed this group on May 21, 1947.

Hjs statistics covering large industries indicated there has been a trend of diminishing output per man hour. I think Mr. Kelly's question of how are we to obtain a fair day's work for the high hourly rates we pay can be answered fairly by saying management should set the pace by putting more effort into its own executive positions and should encourage its supervisory and foremen groups to do the same. We must remember we are always happier at our jobs when the man next to us is enjoying his. Supervisors and foremen who display enthusiams for the job at hand will constantly create worker enthusiasms for the same job. Worker enthusiasms raise output and our goal is achieved pleasantly.

An honest analysis of our own attitude toward our associates and employees is something we should not neglect when faced with the problem of obtaining a fair day's work for the rates we pay.

Modern management should learn to accept a wide variety of new responsibilities. For example, there are a great many cases where business executives fail to create either good will or good public relations solely because they do not put something of themselves into the solution of their problems. I think you will agree with me when I say that public relations are a responsibility of top management, for it is the conduct and policies of top-bracket management that come to the attention of the public.

With this thought in mind, I feel community activities should be given more consideration. Beginning with the young people in our neighborhood, we can create good will by taking the local elementary school classes on a conducted tour of our factories. This should be a natural thing for us to do, since it gets us acquainted with these young folks and we are no longer the big stranger in their midst.

Among our neighbors, who are a bit older than the grade school group, we can take an interest in individuals who are making better than average progress in their schooling. By learning who these particular individuals are, we may make it a point to be helpful to them in many ways.

Later on, when they start business careers, we could expect to receive a number of ambitious and friendly neighbors into our organization. Any company with a policy of this type is certain to have the good will of the community in which its plant is located, and if a company has a policy of promoting employee welfare, there will be small doubt about the success of its operations.

An example of our interest in the employee is a practice we recently initiated that serves to create new opportunities for working men of our organization. For several years we have had an educational program under which promising young college graduates are brought into our organization for industrial training. These men are given a chance to spend some time in all of the major departments of our plant. I am proud to tell you that the results have been most gratifying to us and we presume satisfactory to the young men, for not one of them has left our employ and they all show considerable interest and enthusiasm in the knowledge which one acquires through association with the workingmen of our plants.

I am also proud to tell you that the workers who have been entrusted with the training of these young men all exhibit a tremendous amount of pride in the progress that is being made.

Within the last few weeks we have begun a new program, which is intended to create new opportunities for our workmen. What we are doing is this: We select from our employees a group of men who have been denied the advantages of advanced education for one reason or another. The individuals comprising this group will be sent to college for a term of intensive courses. They will be paid their regular salaries or wages, just the same as if they were at work every day. When the courses are completed, they return to their former jobs, where it is presumed they will be equipped to make progress that would otherwise have been impossible.

I can tell you frankly it is the avowed purpose of our company to maintain good will and understanding between men and management. Acts of good will, fairness and a genuine interest in our employees are all considered to be part of the routine conduct of our business.

I trust I might say a little to you about the management of our city. We all know that not too many years ago our municipality was highly regarded and was considered the workshop of the world.

While I have covered briefly a few of management's responsibilities in business, I think it only proper that the management of our city and county departments receive the same careful consideration that seems to be necessary if our businesses are to be successful.

We cannot have a community that is looked upon as a dying city and expect the businesses in such a city to prosper. Industrial leaders must take a wholesome interest in the management of our community so that the community and its industries prosper as a team.

During the past week I had a discussion with an outstanding business executive, who stated that our city has lost it standing as a progressive community. He tells me that one of the largest trust funds in the country, operating with its main office in Philadelphia, makes practically all its investments in companies outside Philadelphia. They prefer to

supply funds to wide-awake municipalities teamed up with business and industry.

The Committee of Fifteen are finding the various city and county departments poorly equipped, inefficient and in no sense modern in their scope.

I am sure that an improvement in our city could be had if our business leaders were more mindful of the assistance they can give to better the administration of this city.

I am hopeful that a greater interest in civic matters on the part of our business leaders might serve to bring Philadelphia back to its rightful place as a great city.

I trust I have not tired you with too serious a talk on the subject of management's responsibilities.

Thank you very much for your patience.

Paint Defies Flame. (*Science Illustrated*, May, 1948.)—A new fire retardant paint, the only one listed by the National Board of Fire Underwriters, is called Albi-R and is made by the Albi Manufacturing Co. It can be used on wood, plywood, fiber board and fabric. The Albi coating retards fire because, when heated, it puffs up, providing good insulation. After the fire has been extinguished, the coating can be scraped off, leaving undamaged wood underneath. In a two-room test bungalow, one room of which was painted with Albi-R and the other with ordinary paint, a fire completely destroyed the one half and left the Albi-painted half hardly warm.

Business Teams With Research.—The aerosol method has proved so successful and profitable in controlling several of the worst greenhouse pests that commercial application is running neck and neck with an active research program. Commercial growers are so anxious to apply the newest improvements that several consult regularly with the Federal workers to keep informed of the progress of their tests. Some of these growers then risk applying on commercial scale the treatments the Bureau of Entomology and Plant Quarantine investigators regard as most promising. The Bureau's research program benefits in turn from the practical experience reported by the commercial greenhouse men. Thus the differential between research results and practical benefit is readily and quickly determined and adjustments made.

The aerosol method is most familiar to the public in the form of an aerosol "bomb" loaded with an insecticide dissolved in a gas liquified under pressure—usually DDT or pyrethrum or a combination of the two in Freon gas. When the nozzle is opened the gas escapes and carries the insecticide in a highly effective atomized mist or cloud.

DDT aerosols have been used widely in greenhouses, and other of the new insecticides are under test. The aerosol equipment at Beltsville treats a greenhouse at the rate of 1,000 cu. ft. in 4 sec. Using the DDT aerosol, experimenters have treated more than 150 varieties of plants with injury to only two—cucumbers and kalanchoes.

A newer chemical, hexaethyl tetraphosphate, when used in aerosols, has given strikingly good control of several of the most troublesome greenhouse pests—red spider, several aphids, whitefly, and thrips. Last year several greenhouse operators applied this chemical in large-scale tests using the dosage the Federal experimenters developed. It proved highly effective, particularly against the red spider. Greenhousemen were able to stop hand "syringing" of roses. Freed of the pest, the roses yielded 30 to 50 per cent more flowers from the same bench space. Red spider and aphids have also been serious pests of carnations. Under some conditions this hexaethyl tetraphosphate aerosol may injure tomatoes and some chrysanthemum varieties.

Newest of the insecticides to be tried in aerosols is a complex organic chemical named parathion. Although this material has proved highly effective against many pests and has not injured any of the more than 50 greenhouse crops on which it had been tested, nevertheless parathion is very poisonous to warm blooded animals and the Bureau is not advising its use. If it is used extreme caution is advised especially in closed spaces.

R. H. O.

THE STORY OF THE NEW BENJAMIN FRANKLIN HALF-DOLLAR.[1]

BY

MRS. NELLIE TAYLOE ROSS.[2]

I am greatly complimented and most appreciative to have been invited here tonight to join in a celebration of the latest honor that has come to the great American patriot, Benjamin Franklin. It is most fitting that such a celebration should take place in this historic city, which is rich in traditions and with which the fame of Franklin was so closely linked. It is also fitting that it should be sponsored by an institution of such outstanding distinction as this which bears his name.

Dr. Allen and his associates, through whose grace I am here, did not intend, I believe, when first they approached me about coming, that I should be asked to talk for my supper. The idea seemed to develop, along with the planning, that you might be interested in hearing from one close to the Mint, something of what is involved in the changing of a design on a coin; and a few observations, perhaps, on related subjects.

You might think, if you have given no thought to the subject, that it would be a small matter to change the design of a coin, it being such a small object. There is much more to it, I assure you, than first meets the eye.

By what authority, you may ask, can a change be made? It is by authority of the Congress of the United States. The Coinage Act empowers the Director of the Mint to change the design of any coin, with the approval of the Secretary of the Treasury, but specifies that a change may not be made more often than once in 25 years; and then it is not mandatory.

Any alteration in the physical aspect of one of our coins is quite a serious responsibility. Most people probably pay little attention to the details of any of them, but let an innovation be proposed and it becomes, at once, a matter of intimate, personal interest to almost everybody. And well it may be—for after a new design is impressed upon a coin and it is once launched, it goes on and on into circulation until it is too worn for use.

In a recent radio talk I ventured to suggest this idea, in connection with the new Franklin piece, saying in effect, that when a coin is once released for circulation the public must accept it—like it or not! I had

[1] Full text of a talk given in Franklin Hall on the evening of April 29, 1948, when the new Franklin half-dollar was first seen. After the talk Mrs. Ross presented to The Institute Museum an exhibit showing how the coin was designed and produced.

[2] Director of the U. S. Mint, Washington, D. C.

in mind the legal restraint against frequent changes of design. With all speed a letter came to my office, written in high dudgeon, by somebody in a distant state, charging me with being a typical Federal bureaucrat, arrogantly snapping my fingers in the face of the public.

The first concern of us all—the public—and certainly of officials directly concerned when a change is determined upon, is that the design to be adopted shall be worthy of a place on a United States coin. It must have artistic merit; it must have meaning. That is, it must tell a worth-while story in its symbolism and historic suggestion.

We all know that the history of ancient civilizations is, in considerable degree, traceable through coins that have been handed down; handed down by people who had lived and died centuries before the advent of the printing press. Needless to say, it is imperative that the devices, characters, and lettering on a coin's design be so developed and arranged as to be amenable to the coinage process. Only to a sculptor of recognized skill should, therefore, be entrusted the task of producing a coin design. The mere fact of one's having attained fame as a sculptor gives no assurance that he can produce a design satisfactory for use on metal, in bas relief. Some famous artists are shown, by Mint records, to have made dismal failures in that direction. Best results, I mention in passing, are to be expected from Mint sculptors who know something of the exigencies of the coinage process. A design may be perfectly beautiful in a clay model, the size of a dinner plate, and may have been executed by an eminent sculptor, but when reduced to the size of a coin, be lacking in distinction, or be unadaptable to coinage.

At best, the artist's product meets with many vicissitudes from the time of its appearance in the clay model until it finds its place on the little round of metal in the guise of a coin. Mint experts feel that they also, along with it, go through many vicissitudes in their effort to bring the artist's concept into harmony with legal requirements with respect to size and weight, and with the mechanics of coinage. That, as a rule, is a difficult task. The "ironing out of the bugs," as they say in the Mint, calls for good head work a-plenty, and for most meticulous hand work also.

The law itself prescribes the weight and content of a coin, as well as certain legends and characters it must bear. The design therefore, must permit such flow of metal as will produce the correct weight, and size. Thickness must be taken into account. The relief of the dominant details must be high enough to produce a handsome, clear-cut effect, but if slightly too high here or there, in relation to the outside rim, or in relation of one side to the other, rubbing and rocking will result, which prevents perfect stacking, and perfect packaging.

As a rule it is not until the design is reduced and impressed upon the working dies and not until they are subjected to experimentation, that flaws in the design (from the minting standpoint) reveal themselves.

Sometimes the models have to go back to the artist—more often Mint experts, in collaboration with the artist, make necessary alterations in the detail. They are not, as a rule, evident in the finished coin.

The reason is now clear, I hope, why we cannot announce far in advance the exact date a newly-designed coin will be ready to leave the Mint and start on its way into circulation.

You may be wondering how it came about that the portrait of Benjamin Franklin found its place upon the fifty-cent piece together with a replica of the Liberty Bell. For several years I had harbored the hope that during my tenure in the Mint these two features might be incorporated in a design for one of our coins. From time to time, letters have come in to my office urging the use of Franklin's portrait on the one-cent piece; probably because of his identity with the maxim "A penny saved is two-pence clear"—often misquoted "A penny saved is a penny made." You will agree, I believe, that the fifty-cent piece, being larger, and of silver, lends itself much better to the production of an impressive effect.

During the war it appeared for a time that the addition of one or more denominations might be required to ease the demand for one-cent pieces—the enormous production of which, under pressure of demand, was straining the coinage capacity of the Mint. The necessity did not materialize. In order to be ready, however, for any contingency, we assigned to our highly skilled sculptor in the Mint, Mr. Sinnock, the task of evolving a new design, to embody a likeness of Franklin and a representation of the Liberty Bell. That design was in readiness for the fifty-cent piece. I mention with sorrow that Mr. Sinnock's death occurred one year ago.

When, after the war, the extraordinary pressure of work upon the Mint had eased, we determined that the half-dollar should be given a "new look"—it having worn its old attire since the year 1916. We resolved that the figure of Liberty with her flowing robes on the obverse, and the eagle on the reverse, should give place to Franklin and the Liberty Bell; assuming of course, the approval of the Secretary of the Treasury. This, happily, was readily forthcoming with his expression of pleasure in the choice of the design.

I point out that the new fifty-cent piece is unique in one important respect. On it, the eagle is for the first time given a subordinate position on any of the silver coins of denomination above the dime. The coinage law under which we operate and which was enacted in 1873 provides that each of these silver coins must bear the figure of an eagle or representation thereof; ambiguous language that, you will agree. What could be a representation of an eagle but an eagle itself! We tried to persuade ourselves that the eagle was supposed to represent strength and freedom and that the Liberty Bell would suffice as a representation thereof. But in the end we decided that discretion was the better part of valor and

we had better put it on to assure conformity with the law. Accordingly, Mr. Roberts, our capable sculptor at the Mint, very cleverly, and with pleasing effect, we think, added a small eagle at the right of the bell to balance with *E Pluribus Unum* on the left of it.

The subordination of the eagle on this particular coin is an interesting coincidence inasmuch as Benjamin Franklin, as Dr. Allen reminded me, condemned, in strong and picturesque language, the use of the eagle as a United States emblem. He called it a bird of prey, of bad moral character—a coward, lazy. The turkey, he contended, was more worthy and being a distinctly American bird would be a more suitable emblem.

Benjamin Franklin is also on record as disapproving the use of portraits on coins. Royal heads he had in mind apparently. He advocated the substitution of proverbs profitable for human reflection. Renowned for wisdom as Dr. Franklin was, he no doubt had some of the weaknesses to which most human flesh is prone; even a little vanity perhaps. Had he known in his day, that 150 years hence his image would be placed on a coin of this, his native land, to whose service his life was consecrated, we may assume, I believe, that he would not have been seriously displeased.

You of this company will agree, I am confident, that it is a distinction, well-merited, in view of his outstanding service to this country in its infant years, when it was struggling to establish itself as a free nation, and in view of his contribution to human progress in general.

Benjamin Franklin was truly an amazing person, as is evidenced in the eminence he achieved in the various roles he filled—statesman, scientist, philosopher.

It is difficult to define the attributes that make for greatness. It is certain that Benjamin Franklin had, in a high degree, such qualities of heart and mind as enabled him to command the confidence, even affection, of people in all walks of life who came within the orbit of his influence. They were, moreover, qualities that enabled him to win support to his objectives.

He was a man of unpretentious bearing, we are told. His attire was simple compared with that of most gentlemen of his stature, in a day when velvet and lace frills contributed much to masculine pulchritude. And yet in any company he entered, at home or abroad, he was at once an arresting, commanding figure. Scholars, statesmen, authors listened to him with great respect. Sophisticates at the court of Louis Sixteenth vied with one another for his attention. Marie Antoinette herself, influenced by his persuasive utterances, according to historians, took up the cudgels in support of the Revolutionary cause of the colonies.

Franklin's faculty for establishing strong friendships stood this country in good stead. The friendship that he won from the people of France during his long sojourn there as our envoy, proved to be, as we

know, of priceless value to this country. His one great objective was to win a binding alliance between that country and ours. This he accomplished by dint of great patience and consummate tact. The signing and sealing of that pact was doubtless the greatest triumph of his life. It meant arms for our soldiers with which to fight. It meant money for food and clothes for them and shoes for their feet in a time of direst need.

As we ponder the value of this aid, the question arises, what, without it, would have been the destiny of this country? What would have been the destiny of us, in this generation? Who can reckon our indebtedness to Benjamin Franklin for that service?

As for his contribution to science, be assured I would not presume to exalt its importance in this erudite company, composed largely of persons who are themselves scientists of recognized eminence. I regret to say I can not talk the language of scientists and I fear I could not understand if they tried to explain it to me.

Monumental as were the deeds of this versatile genius in the fields of science and statesmanship, I doubt if they have served as much to keep his name alive down through the generations, even to this day, as has his homely, down-to-earth philosophy, expressed in language that everybody can understand, even the most unlettered person. The fact that his maxims have lived, are still familiar household words, and almost any day appear somewhere in public print, testifies to their general acceptance as sound guides for human conduct, whether or not they are consistently practiced.

Franklin is widely renowned as the apostle of thrift. At this time when a good part of the world is hungry and when a beefsteak here at home costs almost a king's ransom, it seems only good common sense to heed his precepts on thrift. All of us, I am sure, would like to hold on to a few shekels for future needs. Poor Richard says that "He that goes a borrowing, goes a sorrowing."

Thrift I count among the cardinal virtues, quite convinced that it has vital bearing upon the average person's chances of rising to high achievement, and even more important, vital bearing upon character.

It is only by the practice of thrift that a young person starting his career can expect, unless he has wealth bestowed upon him, to meet his financial obligations as he goes through life. That he must do if he is to preserve his self-respect and command the respect of others. How else can he provide, except by exercise of thrift, for the rainy day, if he is dependent upon his own resources, which is sure to come. How else can he hope to realize cherished ambitions that call for material assets.

That young person who starts out adult life spending all that he makes and accumulating nothing but debts is in a poor position to seize choice opportunities coming his way which might lead to outstanding success, and great usefulness.

Furthermore, Poor Richard says "'Tis hard for an empty bag to

stand upright." We have all seen that truth exemplified in the person who indulges himself in an extravagant scale of living—to keep up, perhaps, with his neighbors the Joneses—which he knows his income cannot support. That person is following a dishonest course, for he is appropriating to himself the substance of others to which he has no right as though he were reaching his hand into their pockets.

Benjamin Franklin's philosophy I point out, was by no means limited to this one subject of thrift. It covered a wide range of human interests. Young men he admonished: "Keep your eyes wide open before the marriage ceremony, half shut afterwards." Good advice that! In exalting the simple life he opines "A little land well-tilled, a little house well-filled, a little wife well-willed, are true riches." Many of Dr. Franklin's most impressive utterances are in verse too long for comment here.

About the Liberty Bell on the reverse of the coin. I am deeply impressed with its significance to us as a country, as a symbol, at this juncture of the world's history. To me it is a soul-stirring thought that on this coin it will go out to the four corners of our country into the hands of practically every American. As one largely responsible for its being on the coin I express the ardent hope that it may be a constant reminder to us all how blest we are to live in this land of liberty; how blest we are that our forefathers had it in their minds and souls to establish in this new country, a free government, though it should cost them their lives, and to hand it down as such to their children of succeeding generations. So brilliant in mentality were those early statesmen who laid the foundation of this government, so forceful of character were they, and sound in integrity, it seems as if Heaven must have endowed them for that especial purpose.

We do well to remember that this precious freedom, bequeathed us by them, is ours, to have and to hold, if we jealously safeguard it and stand ever ready to defend it at any cost.

No condition in this world can be assumed to be static; not even this blessed state of freedom we enjoy, unless it is safeguarded. We know that right now there are forces on the march which are bent upon undermining the order under which we live. They would put an end, if they could, to this system of ours that exalts the dignity of the individual citizen and respects his right to make for himself a place in the sun, according as his talents and industry make possible; that permits every person to choose his own religion, and manner of worship, and to speak aloud his views on any subject, so long as he does no harm to his fellow men.

Enemies of this system would, through open and insidious tactics (mostly insidious), deprive us of such liberties as these and see us in the same mold that they are cast. Seeing the goings-on in the world right now, as we do, we should realize that this is no time for com-

placency on the part of any literate citizen. It is a time for all of us to show a keen awareness of any propagandist activity, wherever it asserts itself, which seeks to undermine our free institutions, and to speak out against it with spirit.

Three weeks ago in Philadelphia I stepped into a little shop. The proprietor told me of a woman who had been there before me. She came asking him to contribute money for an organized group, which gives evidence of being unfriendly to our system of government. Not only did he indignantly refuse and tell her that she was not welcome in his shop making such a proposal, but he proceeded in strong language to tell her what she was doing to herself, her husband, and their children. He pointed out to her that her husband's thriving little business was providing a good living to them all and education for their children, such as would be impossible to them in any other country in the world. She left that shop roundly reprimanded for her disloyalty. If all of us were as alive to our responsibility as citizens as was that man, we could, through the force of public opinion alone, beat down and crush any subversive "ism," foreign or otherwise inspired, that dares to invade this country.

Again referring to the coin. On its face it bears, as do our other coins, the words "In God We Trust." Thus do we as a nation proclaim to the world our recognition that human wisdom has its limitations. Right now our statesmen are grappling with problems thrust upon them by post-war conditions, which are challenging their powers of brain and soul. There are many facets to those problems which make decisions so difficult they seem almost to defy human wisdom. The world's woe cannot be ignored by this strong, highly-favored nation. The general recognition of that fact, which is evident, is a tribute to the character of the American people.

There is one thing we know—this government of ours is not seeking to exploit any nation on the earth, through economic or any other advantage. Our statesmen have iterated and re-iterated that truth. All it wants is to help; to help those nations that are stricken or tottering back on their feet again. It wants to put them in a position where they can work out their economic rehabilitation and save, or achieve their freedom, while we keep our own secure. It is plain that the overthrow of freedom, in one country after another, if it is permitted to go on, cannot fail to menace our own.

The concern and compassion which this country is showing for the double tragedy of economic distress and loss of freedom, which multiplied millions of people over the earth are suffering, are in accord with the teachings of Christ. In the untiring labor of our national leaders seeking to reach out a helping hand and in the material treasures which we the people are pouring out, we obey the scriptural injunction "Bear ye one another's burdens and so fulfill the law of Christ." That being

true, we have reason to take heart, though the sky is dark over the world at the moment, and to trust that through Divine guidance the mighty effort which we are making will be effective in helping bring back peace and order to the world, and speed the time when liberty-loving people in any part of it can achieve and maintain a civilization based upon the principle of human freedom.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

LARGE PHOTOMETRIC SPHERE.

Measurement of the total light output of lighting equipment is made with the integrating sphere, a device by which the light is so thoroughly diffused that the total flux may be determined by a single observation at any selected spot on the sphere. With the increase in physical size of light sources, the National Bureau of Standards found it necessary to construct a sphere large enough to accommodate the largest commercial and research fixtures. The Bureau's new 15-ft. integrating sphere—believed to be the largest in the world—has extended the photometric study of light sources to include those beyond the capacity of the Bureau's other spheres, which range up to 7 ft. in diameter.

The most useful measure of the value of a light source is the rate at which it supplies light. In the measurement of this luminous flux, all light emitted, regardless of direction, is counted because present lighting practice utilizes all such flux by means of suitable reflectors. Essentially the method of test is to place a light source or lighting fixture in the center of a standard white-lined spherical room, the integrating sphere, and to measure the photometric brightness of a spot on the wall of the room. If the spot observed is screened from the direct rays of the fixture, the photometric brightness of the spot in the ideal case varies in direct proportion to the total luminous flux emitted by the fixture.

It would, of course, be much easier to build the room in the form of a cube instead of a sphere. But any light from a fixture directed initially into one of the corners of the cube would fail to contribute its full share to the brightness of the inner wall; so the result obtained with a cube would depend on how the fixture was oriented with respect to the corners of the cube. The spherical shape, on the other hand, has the unique property that any flux reflected with perfect diffusion from any part of the inner wall illuminates all other parts of the wall uniformly. Therefore in an ideally constructed integrating sphere the reflected light flux falling on any part of the sphere is exactly equal to that falling on any other part. It follows that the photometric brightness of any portion screened from the direct rays of the fixture is exactly equal to that of any other such portion. Thus, only one spot need be measured.

All parts of the inner surface of an ideal integrating sphere must have the same reflection factor, and each spot must diffuse perfectly the incident light flux. Furthermore the ideal sphere must be perfectly

* Communicated by the Director.

empty. In the sphere recently installed at the National Bureau of Standards, great care was taken in applying the sphere paint to the inner wall to insure a coating of uniform reflection factor. The sphere paint was selected especially to give as close an approach as possible to perfect diffusion of reflected light. The reflection factor was kept high so that even if the first component of the reflected flux were to fall somewhat short of the ideal perfect diffusion, the components added by multiple reflection would materially improve the approximation. In addition, the effect of an imperfectly diffusing inner coating may often be minimized by the use of a test method in which the fixture is substituted for a carefully measured standard fixture of the same type.

Obviously, however, the sphere cannot be perfectly empty. The source has finite dimension, and there must be in the sphere the wires and supports for the fixture. There must also be an observing hole in the sphere and a screen between the fixture and the spot on the wall to be observed. If these obstructions are large compared to the area of the sphere, they prevent an appreciable amount of light flux from reaching the observation spot so that the photometric brightness is erroneously low. To minimize this error, the screen between the fixture and observation spot is made as small as possible compared to the area of the sphere wall. Also, the screen, the fixture, the conduits for wires, and the supports are painted with sphere paint, though the light source, itself, cannot be so treated.

The development of large lighting fixtures such as those utilizing the fluorescent lamp emphasizes the difficulties. The 5-ft. 100-w. fluorescent lamp, for example, has a superficial area of nearly 400 sq. in. For this area to remain below the desired upper limit of 0.5 per cent, the sphere area must be 200 times that of the source. This consideration alone would require a sphere of about 13-ft. diameter. There is an added factor that enters into the question. When a full analysis of the details of using the sphere is made it can be shown that no part of the source should approach too closely the inner wall of the sphere lest appreciable nonuniformities in inner-wall brightness be produced. All these factors lead to the conclusion that the sphere diameter should be at least 50 per cent longer than a thin cylindrical source.

The inside dimensions of the Bureau's 15-ft. sphere, weighing more than a ton as installed in a specially designed high-ceilinged room of the new Materials Testing Laboratory, is accurate to within a quarter of an inch along any diameter. Made of molded mahogany plywood, the sphere is composed of 24 identical segments with two polar caps to permit the lowering (or supporting) of large fixtures in the sphere. One half is movable and opens on hinges, permitting easy access to lamps and fixtures placed in the sphere for test. The movable half may be completely detached so that the fixed hemisphere may be used as a hemispherical integrator for special tests. The increased size of the

new sphere permits the measurement of cylindrical sources up to 10 ft. long.

CHROMATED PROTEIN FILMS INHIBIT CORROSION.

Chromated protein coatings[1] offering a convenient, inexpensive means of protecting metals—especially zinc, iron, brass, and aluminum—during outdoor storage in mildly corrosive atmospheres have been developed by Abner Brenner, Grace Riddell, and Robert Seegmiller of the National Bureau of Standards. The protective value of such films is somewhat better than that afforded by chemical surface treatments and is much superior to that of corrosion-inhibited oils and waxes. The metallic surface to be coated is first dipped in casein, albumin, or gelatin; the resultant film is then impregnated with chromate, which both hardens the film and inhibits corrosion.

The wartime scarcity of many nonferrous metals led to the extensive substitution of ordinary carbon steel for copper, brass, aluminum, and stainless steel in both military and civilian uses. While the steel was generally protected with zinc coatings, the tendency of the zinc to form objectionable corrosion products brought about a widespread use of chromate films on the zinc. These films were formed on the surface by chemical attack in aqueous chromate solutions and, though only a few hundred-thousandths of an inch thick, were useful in inhibiting corrosion. However, as this was apparently due to the presence of minute amounts of soluble chromate, slowly liberated by the action of moisture, it seemed possible that an enhanced corrosion resistance might be obtained by applying a large quantity of chromate to the metal surface. The National Bureau of Standards therefore undertook an investigation in which proteins were found to offer a good medium for increasing the amount of chromate on the metal surface since they are basic and readily absorb or combine with chromic acid. Although initially developed at the Bureau as a substitute for chemical surface treatments of zinc, the chromated proteins are also of value in protecting aluminum, steel, brass, and other metals.

The principal constituents of the chromated protein films are a corrosion inhibitor for the metal, a protein which acts as a vehicle for the inhibitor, a hardening agent, and a bactericide to prevent putrefaction of the protein. The chromate always serves as the inhibitor and may act as the hardening agent and the bactericide as well. However, other materials such as formaldehyde, tannins, or certain salts of the heavy metals can be used as the hardening agent.

The four functioning constituents of the film can be applied in a

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[1] For further technical details see "Chromated Protein Films for the Protection of Metals," by Abner Brenner, Grace Riddell, and Robert Seegmiller, in *J. Electrochem. Soc.* for March, 1948.

single step or in several steps, according to the compatibility of the agents and the degree of protection desired. In the "two-step" process, which is usually the most satisfactory, the metal if first dipped into an aqueous protein solution. When the resulting protein film is dry, it is immersed in an acidified chromate solution for ½ to 3 min. and allowed to dry without rinsing. The preparation of the protein solution varies somewhat with each protein. Gelatin is dissolved in water by heating gently; albumin may be dissolved in water at room temperature by stirring; casein is dispersed in water and brought into solution with the addition of 25 ml. of ammonium hydroxide per liter of solution. The chromate solution contains chromic acid (0.5 to 2 per cent) or a dichromate of zinc, iron, or nickel (1 to 10 per cent).

A simpler "one-step" method of forming the inhibiting film by a single immersion in a solution containing both the protein and the chromate has the disadvantage that the solution slowly deteriorates. A solution of this type is made by adding ammoniacal zinc chromate to a solution of casein. The resulting preparation should contain about 10 per cent of casein and the equivalent of about 5 per cent of zinc chromate.

The chromated protein films are yellow and, unless opaque pigments have been added, are transparent. Their flexibility and adhesion are sufficient to prevent cracking or separation when the metal is bent. They are not injured by heating to 150° C., whereas most chromate films produced chemically on zinc lose much of their protective value at 100° C. Thickness depends principally on the concentration and viscosity of the protein solutions, varying with the type of protein up to about 0.0002 in. This is in contrast to the proprietary chromate films, which usually are not more than 0.00003 in. thick.

When freshly prepared and hardened, the films are almost insoluble in water and are so hard that they cannot be scratched with the finger nail. Exposure to light further hardens some films and renders them still less soluble. However, the films may be quickly removed from metal parts by application of an alkaline solution such as 5-per cent sodium hydroxide. Their removal is thus more convenient and less hazardous than the removal of oil films with toxic or inflammable organic solvents.

The protein solutions, unlike the baths used for direct phosphate or chromate treatments, do not become exhausted and require replenishment, but are fairly stable for long periods. While chromated protein films are superior to direct phosphate or chromate coatings or to oil films for corrosion prevention, their life is less than that of suitable paint coatings. They are more effective on large, regular surfaces than on the sharp edges and corners of small objects like nuts and bolts, where the film tends to pull away.

CONDUCTIVITY CELL FOR VISCOUS MATERIALS.

A new type of conductivity cell developed by Dr. Earl Otto of the National Bureau of Standards now makes it possible to determine with precision the resistivities of viscous liquids, pastes, suspensions, and wetted powders. The apparatus, which also possesses several advantages for use with free-flowing liquids, is simple and rugged in construction, made of inexpensive materials, and so easily and quickly disassembled that its inside surfaces are entirely accessible.

As commercially available types of conductivity cells have been limited to use with nonviscous liquids, studies of the resistivity of the gelatinous pastes and carbon-manganese dioxide mixtures used in dry cells have been confined in the past to investigations of the constituent electrolytes. In recent years dry cells capable of functioning at the low temperatures encountered by aircraft at high altitudes have been urgently needed by the Army and Navy. In connection with the design of several types of dry cells at the Bureau for this purpose, the new conductivity cell was developed to determine separately the resistivities of dry-cell components at the required temperatures. With some alteration of cell dimensions it is expected to be very useful in measuring the conductivities of pastes, glues, viscous aqueous solutions, aqueous cement suspensions, pigment slurries, clay suspensions, moistened soil and other materials. Other suggested applications lie in the textile, plastic, and soap industries and in the manufacture of adhesives, batteries and ceramics.

In the apparatus designed at the Bureau, the electrodes are made of graphite impregnated with paraffin oil, instead of the more usual platinum. The corrosive action of the ammonium chloride electrolyte used in dry cells and the sturdiness and durability of the carbon electrodes make this desirable. The reservoirs of electrolytic material surrounding each electrode are separated by a small-diameter tube that also contains some of the electrolytic material in order to obtain a cell with a satisfactory constant for use with strong concentrations of highly conductive salt solutions.

The two graphite electrodes, like those ordinarily used in D-size dry cells but shortened to about $1\frac{3}{16}$ in., are inserted in glass tubes about $2\frac{3}{4}$ in. long and $1\frac{1}{8}$ in. in inside diameter. These larger tubes are joined by a 3-in. tube having an inside diameter of $\frac{1}{4}$ in., the connections being made with rubber stoppers. The extreme end of each electrode has an electrolytically deposited coat of copper, to which is soldered a lead wire. The leads are protected by glass or plastic tubing, the ends of which are embedded in the top and bottom rubber stoppers. The large glass tubes are graduated to permit insertion of stoppers to the same depth each time the cell is assembled, and the stoppers are connected by springs to prevent leakage of material.

Loading the conductivity cell is not difficult. Free-flowing materials

are first poured into the lower electrode compartment. The small-bore middle portion, with top section attached, is then fitted into the bottom section, forcing air and excess liquid through the connecting tube into the top compartment. Additional liquid is poured in to fill the top section, and finally the topmost stopper is inserted, expelling any excess through an overflow tube. With an electrolytic paste the procedure is the same. However, care should be taken to get no paste in the overflow tube, and the paste must be promptly gelatinized by immersing the assembled cell in hot water. A slurry is loaded in the same way as a liquid, except that considerable force may be required to join the two upper sections to the bottom section. A wetted powder requires tamping in all three tubes.

Although the new cell is not unbreakable, it will withstand considerable rough handling. Replacement of any one part requires only a few moments, and some parts may even be replaced without a redetermination of the cell constant. On the other hand, an ordinary conductivity cell requires expert glass blowing to repair a break, and the repair must be followed by replatinizing of the electrodes and a recalibration of the cell.

While designed primarily for use with viscous materials, the cell also has some advantages for the study of free-flowing liquids. Since it may be wiped dry before loading, there is no need of rinsing with the liquid under test, as is done before a commercial conductivity cell is used. Following a determination the solution may be diluted or otherwise modified and a further resistivity determination made, or it may be returned to storage with very little loss in volume.

The apparatus may be used in conjunction with any of the usual methods of measuring electrolytic resistances. Reproducibility has apparently been limited mainly by the bridge that is used. However, duplicate sets of data have been found to check within 0.2 per cent.

ELECTRON MICROSCOPY OF WOOL FIBERS BY A SHADOWED REPLICA METHOD.

The National Bureau of Standards is engaged in a broad research program on the causes and nature of wear in textiles. Among the phases under investigation are the degradation effects of various physical and chemical agents. A fundamental approach to the problem is being made through the study of organic fibers by means of electron microscopy. In cooperation with other members of the electron microscopy laboratory and the textile laboratory, Max Swerdlow and Gloria S. Seeman have developed a simplified shadowed replica technique that is comparatively simple and rapid. Through this technique, fine details of the morphology of the wool fiber, both in its natural state and after various treatments, have been revealed.

The electron microscope has been a useful tool for observing objects

which are thin enough or which are sufficiently small and adequately dispersed to allow the proper scattering and transmission of electrons in the conventional 50 KV. microscope. The high resolving and magnifying powers of the electron microscope have thus been used with considerable success in the study of the pigments, smokes, viruses, bacteria, and a variety of other colloidal particles. On the other hand, when efforts are made to study organic fibers, ordinary techniques of direct preparation fail.

Partial solutions to the problem have been found by those concerned with the study of wool fibers. Fragments of triturated fibers of reduced and methylated wool are not adversely affected by the intense beam of electrons and are in part transparent to it. Such techniques, however, are very limited. Not only do they preclude the practical prospect of obtaining information about the surface structure of the fiber, but the possibility of giving the same fiber repeated treatment is eliminated because of the mechanical disorganization and chemical alteration produced.

The limitations of direct methods of surface observation by electron optical means has led to the development of ingenious and devious techniques for preparing thin film replicas of the surfaces of electron-optically "opaque" materials. The improvements and variations of the basic replica methods reported by a number of resourceful workers has been successfully applied to the study of many bulk materials. None of these techniques, however, is directly applicable to degraded wool fibers, since the use of excessive heat or crushing pressure in molding the replica introduces undesirable conditions. Moreover, most replica methods involve destruction of the specimen. This too, eliminates the possibility of performing additional treatments on the same fiber.

In order, therefore, to augment the data on the structure of the wool fiber and to correlate these observations with results previously obtained by the direct disintegration of the fiber as well as by other methods, a simple, rapid, faithful replica technique was developed. This system of specimen preparation successfully combines a method useful for optical and electron microscopy. It involves making a negative replica of the wool fiber in a thermoplastic film which is thin enough to examine directly in the electron microscope and which may be shadow-cast with a suitable metal for added contrast.

Two thermoplastic materials, ethyl cellulose and polystyrene, can be used with about equal success. When a suitable solution of the resin is poured onto a standard glass microscope slide a thin film (about 0.4 microns) is formed upon evaporation of the solvent. The separated fibers, free of grease and dirt, are then laid upon the thermoplastic lacquer, and another glass microscope slide placed on top of the fibers to make a sandwich with the plastic film. The sandwich can be held

together with the aid of a C-clamp. Reasonable care must be exercised in order not to twist the assembly. The clamped glass sandwich of film and fibers is then heated in an electric oven for about 20 min. at 90° C. The thermoplastic is thus softened to the point where it will flow and form a faithful replica of the surfaces in contact with it. The factors which affect the quality and resolution of the plastic replica are time, temperature, pressure, thickness of the film and diameter of the fiber. To achieve the proper balance of all these elements is not a difficult problem inasmuch as the limits of control are not too critical. One or two trials ordinarily provide sufficient experience to make numerous acceptable replicas in a comparatively short time.

After the sandwich has been cooled and separated the wool fibers usually come away with the uncoated glass slide, or else they can be brushed out. These fibers having once been "fingerprinted" can be saved for further chemical or physical treatment and subsequent replication.

Shadow casting provides added contrast as well as a three-dimensional aspect to the surface details of the replica. A very thin coating of evaporated chromium is deposited obliquely upon the plastic surface. The elevations and depressions in the surface replica cast characteristic shielded radiation shadows, just as their larger counterparts would cast with oblique illumination, for example, the light of the setting sun. Where no metal is condensed transmission of the incident energy is a maximum. Where thick elevations and ridges occur transmission is a minimum.

The chromium shadowed thermoplastic replicas are then examined in an ordinary light microscope. Photomicrographs may now be taken of them. The glass slide bearing the negative replicas may also be inserted in a photo-enlarger, or desired areas may be selected for further observation in the electron microscope. In the latter case ⅛-in. No. 200 stainless steel specimen screens are placed over the desired areas with the aid of a low powered microscope. The glass slide bearing the replica and the specimen screens is slowly immersed into a dish of water The film with the screens still in place can thus be floated free of the glass and retrieved from the surface of the water by turning it over and out with a dry glass slide or a piece of paper. After drying, the thin shadowed plastic replica supported on the specimen screen is ready for examination in the electron microscope.

Thus, with this method, the structural changes in textile fibers resulting from various chemical and physical factors can be studied. Alterations in surface structure brought about by such factors as abrasion, flexing, repeated loading, acids, alkalies, chlorination, heat, sunlight, moisture, and other elements of degradation may be studied. The manifestations of fiber structure may in turn be correlated with the morphological modifications resulting from actual wear in service. The

fundamental problem of the molecular structure of organic fibers cannot be solved by electron microscopy alone, but considerable information may be determined that is of interest to the textile technologist and to those concerned with the subject of wear resistance.

With this in view attention was concentrated on the study of wool. The wool fiber as shorn from the sheep generally consists of three principal concentric layers—a thin outer covering of scales (cuticle), a middle region (cortex), and a central core or pith (medulla). It has been suggested that the ability of wool fibers to felt, tangle, and curl is dependent upon the direction and shape of the imbricated scale structure, and that the cuticle serves to protect the fiber from chemical and mechanical degradation. It has also been suggested recently that the three dominant cellular structures are encased in an amorphous material which serves both as a matrix and as an intercellular cementum, and that the cuticle layer is in reality covered by this same matrix material.

The present study confirms, at least partially, this theory of the architecture of the wool fiber. Electron micrographs of the surface replicas of mechanically abraded and unabraded wool fibers reveal that the scale is inhomogeneous and consists of a double layer. The outer layer is a smooth covering for the under structure and shows no specific surface feature. Other investigators have shown this "amorphous plastic layer" to be readily digested in an enzyme as is the featureless intercellular cementum which exists between the scale and the cortex as well as between the cortical cells themselves. The similar reaction to enzymic treatment suggests that these smooth featureless layers are of the same composition.

When this lacquer-like covering is removed by abrasion a rigid striated structure is revealed. The corrugations (ridges and furrows) run more or less parallel to the longitudinal axis of the fiber. They are a feature of the scale itself and are not dependent upon, or a reflection of, the formation and size of the cortical cells. This is borne out by the fact that this corrugated structure is seen in the overhanging portions of the scales under which there is no cortex. Upon additional abrasion the scales are polished away leaving a smooth filamentary structure with slight vestiges of the former imbricated surface. More rubbing removes the next amorphous plastic layer under the scales and exposes the cortical cells themselves inbedded in the cementum. By this time the fiber no longer manifests its characteristic filamentary structure and, as such, is destroyed.

The fabrics studied were mechanically abraded by means of an apparatus [1] designed by Dr. H. F. Schiefer of the Bureau's textiles laboratory. A rotary disc of parallel, flat metallic strips is applied to the

[1] H. F. Schiefer "Solution of Problem of Producing Uniform Abrasion and Its Application to the Testing of Textiles," *J. Research* NBC, **39**, 1 (1947), RP 1807.

fabric. During the abrasion process fragments of the cloth fall off. This debris as well as the fibers bordering the hole worn into the fabric were examined. Hundreds of specimens were obtained and studied. Electron micrographs, taken at magnifications of 716 and 3600 diameters for example, when subsequently "reversed" and enlarged optically about 2.5 times give total magnifications ranging from 1400 to 9000 diameters.

THE FRANKLIN INSTITUTE.

ANNUAL REPORT OF THE BOARD OF MANAGERS FOR THE YEAR 1947.

It was announced at the Annual Meeting in January that the report of the Board of Managers on the condition of the affairs of The Institute for the year 1947, as provided for in the By-laws, would be deferred until a later meeting in the spring. The President now presents such report herewith on behalf of the Board of Managers.

Membership.

Our Membership at the end of the year 1947 totaled 5,425, a net loss of 137 for the year, the majority of whom were student members. During the year there were elected 867 new members.

Your officers, membership committee and membership department are conscious of the importance of a stabilized membership. After a careful study it was decided to increase our efforts in general and to place emphasis on two major programs for the purpose of retaining the interest and support of our membership:

1. The series of popular talks under the general topic of "Science is Fun," which have proved so popular that on several occasions the seating capacity of the Lecture Hall has been exhausted. Five or six such talks of this nature are planned for 1948.

2. Active cooperation was sought by our members during the past year in suggesting prospective members. This has proved most helpful. It is planned to cultivate further this close cooperation during 1948 for the purpose of creating in our membership a warmer feeling of interest in their membership directly and in the affairs of the Institute generally.

Meetings.

During the year a total of sixteen stated and joint meetings with other technical societies were held at which the average attendance was 214. The dinners preceding these meetings were apparently enjoyed by the members and their guests who attended. An outstanding meeting was the first public demonstration of color television by one of our medallists, Dr. V. K. Zworykin, of the Radio Corporation of America.

The tenth series of piano lecture-recitals by Mr. Guy Marriner, Director of Music, continued during the spring of 1947 with an extra request recital given in April. The eleventh series opened in October. The increase in attendance during 1947 amounted to 13.8 per cent over 1947, indicating continued appreciation by the public.

It has always been our practice to allow organizations whose aims parallel those of The Institute to use our Lecture Hall and other rooms for their meetings at a nominal charge covering our costs. During the year 1947, thirty-two organizations used these facilities for a total of 252 meetings.

Committee on Science and The Arts.

The Science and Arts Committee met nine times during the year. Twenty-six subcommittee meetings were held. Seventeen medals and two Certificates of Merit were awarded at the annual Medal Day exercises including two Franklin Medals—one to Dr. Enrico Fermi and one to Sir Robert Robinson. Two George A. Hoadley Certificates for long service on this Committee were presented during the year. These went to Mr. W. H. Fulweiler and Mr. C. D. Galloway for service of thirty-five and twenty-five years, respectively.

Journal of The Franklin Institute.

Our Journal, as the oldest scientific magazine continuously issued in the United States, continued to maintain its preeminence among scientific and technical periodicals by publishing

authoritative articles by specialists in many branches of science. The twelve numbers for 1947 contained thirty-five technical papers and a large amount of other material. During the year seventy papers were submitted for consideration, of which eighteen were published and thirty-seven added to the lengthy list of papers awaiting publication. Each month approximately 4,250 copies were distributed—3,050 to members, 550 to domestic subscribers, 350 to foreign subscribers, and 300 in exchange for other publications.

The esteem in which the Journal is held is evidenced by the number of papers submitted and the desire of their contributors to have their work appear in the Journal, even with considerable delay in publication.

Library.

The Library contents were increased during the year by a total of 3,604 volumes by purchase and gifts from the many friends of The Institute.

These additions were as follows:

	Bound Volumes	*Unbound Volumes*	*Pamphlets*	*Maps*
By Gift	340	344	851	171
Binding	1,210			
Purchase	634	54		
	2,184	398	851	171

The total contents of the Library as of December 31, 1947 were:

128,961 Volumes
46,717 Pamphlets
4,443 Maps

Our members and staff as well as outside research workers continued to make constant use of the Library. A total of 13,364 readers consulted the Library staff, through whose efforts they received valuable assistance in their research work. The Library staff was also called upon to give a vast amount of information in answer to numerous letters and over 6,500 telephone calls. Circulation increased over that of last year. In response to requests, 13,000 photostat prints were furnished from references in the Library collections.

During the year 3,406 volumes and 466 pamphlets of a non-technical nature not connected with our field were withdrawn from the Library shelves and given to or exchanged with other libraries.

The publication of a number of foreign periodicals, suspended during the war, was resumed during the year, and copies were received by the Library together with several new ones added to the collection through exchange.

The Library continued to be the only source in this city for copies of the United States, British, and Swiss patent specifications. These are received regularly as published.

An important event of the year was the creation of the Library Fund in Memory of Alfred Rigling, who was with The Franklin Institute Library from 1883–1940. Started with a small anonymous gift and increased by additional small gifts, the Fund is as yet unimpressive in size, but the faith of that first donor should in turn inspire many more to give either large or small amounts.

Museum.

The Museum staff suffered a great loss from the death in March, 1947 of Mr. James D. Lee, Jr., who had been Associate Director in charge of Lighting and Illumination from the opening of the present building. Dr. D. M. Ludlum and Mr. James S. Collins joined the staff—the former as Associate Director in charge of Meteorology and the latter in charge of Graphic Arts, Lighting and Illumination, and the Photographic Salon. Continuing plans inaugurated in 1946, a special group of demonstrators has been employed further to interpret the purpose

and contents of the Museum to visitors. Experiments are being conducted to ascertain how the services of this group can be utilized to the best advantage.

The following tabulation shows the attendance at the Museum and Planetarium:

	Paid	*Free*	*Total*
1945	186,559	82,593	269,152
1946	232,547	75,147	307,694
1947	178,724	72,247	250,971

In making comparisons with other years, it should be borne in mind that, until December 1, 1946, a separate charge of twenty-five cents was made for admission to the Museum and to the Planetarium; after that date, a combined charge of 50 cents was made (in each case exclusive of Federal taxes). Following this rate change, there was an increase in income of 12.3 per cent, but a decrease in paid attendance of 23 per cent.

As in prior years all public and parochial school children from Philadelphia continued to be admitted to the Museum without charge when attending in groups accompanied by a teacher. When attending individually, such children paid only the Federal admissions tax.

The shortage of labor and materials during the war years inevitably led to the cessation of many operating exhibits which fell into disrepair. The members of the staff succeeded during the course of the year in restoring these exhibits.

Many exhibits continue to be offered to the Museum, but pressure on exhibition space and inadequate storage facilities have made a careful screening of such offers necessary before any are accepted. During the year a total of 50 exhibits were, however, accepted for permanent or temporary display, among the more noteworthy of the former being a P51 (Mustang) airplane from the U. S. Army; a model electric generating station and a meter exhibit from the Philadelphia Electric Co.; a recording Pyrometer from the Brown Instrument Co.; a replica of the Wright Brothers original wind tunnel from the late Dr. Orville Wright; a collection of firearms from Mr. Marion Eppley; and a railroad crossing signal from the Union Switch and Signal Co. Outstanding among temporary exhibits were an old-time apothecary's shop, lent by Smith, Kline, and French; a helicopter, lent by the Bell Aircraft Corp.; a turbo-jet engine, lent by the Westinghouse Electric Corp.; a diorama of cold and warm weather fronts, lent by Airology Inc.; a model of an electric power plant, lent by the General Electric Co.; a watch rate recorder, lent by American Time Products, Inc.; a memorial of Frederick Goudy, lent by Mr. Sol Hess; large Japanese binoculars, lent by Mr. H. J. Adicks; a crank shaft for a Diesel locomotive, lent by the Park Drop Forge Co.; a postage stamp collection, lent by the Austro-Hungarian Philatelic Society; and an atomic energy exhibit, from the Enoch Pratt Free Library.

The popular "Exhibits of the Month" were continued, and in this connection an opportunity was given visitors to see the working of the electron microscope purchased for the Research Laboratories. The Junior Engineers group of the Engineers' Club of Philadelphia sponsored an exhibition of Engineering Progress in Franklin Hall from April 5 to 13, which will be repeated in 1948. The display of photographs illustrating industry and industrial processes was continued and an intensified effort to secure the cooperation of exhibitors has produced highly satisfactory results.

A series of television broadcasts from the Museum was inaugurated in August by station WPTZ, with the program under the direction of Dr. Roy K. Marshall. This series included the first telecast of the moon through a telescope. In addition to these regular broadcasts, members of the staff have given occasional studio demonstrations of Museum activities. The fourth series of educational radio programs prepared with the cooperation of station WFIL and the public, parochial, and private schools of this area opened in October. Mr. Armand Spitz again planned the program and supervised the script writing.

The Museum attendance of school, clubs, and institutions groups has mounted continuously since 1943. The figures covering such visits (contained in totals above) including individual students as well are as follows:

	1943	1944	1945	1946	1947
Paid	17,472	27,225	38,368	64,396	65,527
Free	15,000	33,633	42,675	52,140	57,207
Total	32,472	60,858	81,543	116,536	122,734

Work has been done with the Schools of Education of the University of Pennsylvania and Temple University and with the State Teachers' Colleges. This cooperation has taken the form of lectures and conferences in the colleges and also of informal visits to the Museum by groups of student teachers. In-service classes, affiliated with the Museum's activities, have been held, and the Department of Museum Education has been consulted in connection with curriculum planning.

There has been close cooperation with the Philadelphia Board of Education through its Curriculum Office, Visual Aids Department, Adult Education, and other functions. There has also been close association with the parochial and private schools in the area as well as with the Boy Scouts, Girl Scouts, Y.M.C.A., Y.W.C.A., church, and other non-school groups.

The work of the Philadelphia Science Council has been followed, attention being devoted to its activities in relation to the encouragement and development of science talent among students in the schools of this area.

A total of 981 demonstrations was presented in the Fels Planetarium during the year, of which 170 were on special topics chosen in consultation with curriculum officials and teachers as most suitable for school groups. As in the past, Planetarium demonstrations were of two categories—the conventional demonstration in which fundamental information on astronomy is conveyed in non-technical language, and a more spectacular type of demonstration in which special effects are used to arouse unusual interest and to promote attendance.

Research Laboratories.

Bartol Research Foundation.

The Bartol Research Foundation has been working under an extension of its Navy contract for work in nuclear physics and cosmic rays. In addition, it has received a very substantial grant for the development of a high energy particle accelerator.

Following the work reported last year, the Foundation carried on successful cosmic ray observations in B-29 bombers during the National Geographic Society's expedition to Brazil, made in connection with the eclipse of the sun. It has also done considerable high-altitude work with radiosonde balloons, and it has participated in the Navy's expedition to regions in the vicinity of the north magnetic pole.

The Foundation's Van de Graaff generator has been considerably improved, and is operating exceptionally satisfactorily at voltages up to two million. It is probably the most compact generator for its range in the world.

Biochemical Research Foundation.

The Biochemical Research Foundation, of which The Franklin Institute is Trustee, has increased its ties with the University of Delaware. By September 1, 1948, there will be eight post-graduate students working for their Ph.D's in the laboratories of the Foundation. Professor William A. Mosher, Director of Chemistry at the University, has been released from a considerable amount of his work and will give half his time to the direction of these students, who will work upon problems chosen by the Foundation.

The work of the laboratories has gone along well and the year has been a satisfactory one, in spite of losing five of our chief workers. They will be replaced by September.

The Foundation's book, "Neutron Effects on Animals," has had a good sale and has received a number of favorable editorial comments. It promises to become a classic in its field.

Franklin Institute Laboratories for Research and Development.

It is gratifying to be able to report that these laboratories have made progress during the year. By December 31, 1947 the staff, exclusive of shop personnel and consultants, had in-

creased to a figure of approximately 260, with the distribution of scientific functions among three Divisions still maintained.

Conversion, for laboratory use, of the remainder of the old Court Building on our property was started in October, 1947. The additional area furnished by the ground floor and two upper floors of this building into which we moved in the spring of 1948 will go far toward alleviating the space problems with which the laboratories have been confronted in the past.

Acquisition of scientific equipment has, in general, kept pace with the requirements for our various projects. As a scientific and educational institution, we have been able to obtain from the War Assets Administration scientific equipment worth many thousands of dollars at a price within our means. This equipment has been put to immediate use on our problems.

Special acquisitions that provide us with facilities for the investigation of new fields of research are a combination electron microscope and electron diffraction unit; an ultramicrotome capable of producing slices of material less than 1/50,000 of an inch in thickness; and an X-ray diffraction unit.

Other important equipment, such as precision electrical measuring apparatus, oscilloscopes, oscillators, frequency meters, galvanometers, and an optical comparator, has also been obtained. These and other types of equipment have been and will be valuable in our effort toward expanding our industrial research projects.

The electron microscope is capable of magnifying directly 20,000 times. This can be increased to 200,000 magnification by photographic means. The apparatus is being used in the study of metal surfaces and various powdered materials as well as for measurement of particle sizes too small to be otherwise estimated.

The X-ray diffraction unit produces a high speed, accurate X-ray diffraction pattern. This unit will shortly be augmented by certain specialized equipment. It is being used for basic and applied research in various fields, including those of metals, polymers, catalysts, and certain ceramics.

On December 16, 1947 the laboratory for making photoelastic stress analyses, donated by Mrs. David Halstead in memory of her late husband, was duly dedicated. It is now being used in the study of stress problems in both glass and metal sections. It is a memorial of great value to The Institute.

Apparatus has been constructed for the production and measurement of ultrasonic waves in liquids. With these waves as a tool, instruments are being developed to control the commercial processing of rubber and other materials. Special sonic apparatus has also been successfully developed and is undergoing commercial test of principle for the process control of materials. Also in the field of endeavor relating to sound, special techniques and instrumentation have been devised for magnetic wire and disc recording, including a special instrument for graphically recording the magnetic properties of materials. Special techniques have been developed in the field of computers and simulators. Although much of this work has, in the past, applied to Government problems, these techniques are now being studied for industrial application.

The volume of work for various Government agencies has continued to increase, but our aim to make these laboratories primarily a center for industrial research in this area is slowly materializing with twenty sponsors already among our clients and every indication of a steady increase in this number.

Articles have been written and published by members of the staff, descriptive of new developments arising from their basic research. Other developments have been reported at meetings of the different scientific societies.

Hostess Committee.

During the year 1947, the Hostess Committee considered three projects—the establishment of a Children's Room in the Museum, the planting of the lot at 21st and Race Streets, and the furnishing of a new rest room for women in the Laboratory Building and the improvement of the old rest room in the main building. After careful consideration, it was decided that the project for a Children's Room was too large an undertaking for the present, and it was laid aside for action at a future date. Committees have been formed to study each of the other

projects. The Rest Room Committee has already decided what is to be done in the rooms, and some of the furnishings have already been ordered. The Garden Committee has considered possible methods of planting, and will soon decide specifically what plan shall be followed. The Institute is indeed greatly indebted to the Hostess Committee for the services it has rendered.

General.

In addition to its normal departmental routine and its work in connection with various special events which The Institute has sponsored, our Public Relations Department has been active in the continued dissemination of knowledge of Benjamin Franklin. During the year two new leaflets were added to the series which we continue to distribute throughout the country, and numerous requests for odd information about Franklin were answered. *The Institute News* continued to be issued monthly. Consideration is now being given to possibly enlarging and changing the scope of this publication. The Department is already engaged in considering future plans for the proper celebration in 1949 of the 125th anniversary of the founding of The Institute.

Finances.

The financial position of the Institute at December 31, 1947 as compared with December 31, 1946 is indicated by the following comparative summarized statements of assets and liabilities:

Assets	*December 31, 1946*	*December 31, 1947*
Current assets	$ 461,293	$ 662,753
Fixed assets	4,209,402	4,366,250
Less: Reserve for depreciation		(139,137)
Endowment funds (including Notes Payable contra)	1,631,433	1,681,215
	$6,302,128	$6,571,081
Liabilities		
Notes payable (included in Endowment funds contra)	$ 80,000	$ 319,000
Liabilities, deferred income and reserves	90,039	260,548
Endowment	1,631,433	1,681,215
Capital stock and contributed funds	3,995,633	3,954,141
General appropriation fund (surplus)	505,023	356,177
	$6,302,128	$6,571,081

The Institute's endowment at the end of 1947 as shown above may be analyzed as follows:

Unrestricted as to principal and income (including $319,000 advanced to The Institute for operating purposes)	$ 970,549
Unrestricted as to income	534,014
Restricted as to both principal and income	156,695
Unexpended income	19,957
	$1,681,215

The results of operations for the year 1947 are shown in the following statement of income and expenses, it being not possible to compare these figures directly with those of 1946 because of the change made in The Institute's accounting system during the year. This change involved the installation of a cost system as of July 1, 1947 to provide proper control of the costs of the large amount of research work being carried on in The Institute's laboratories.

Operating Revenue:		
Memberships	$ 59,091.78	
Museum	101,410.49	
Other Institute Activities	30,526.74	
Laboratory research projects	1,436,902.61	
		$1,627,931.62
Operating Costs and Expenses:		
Museum	279,302.14	
Library, less amounts transferred	46,748.90	
Other Institute activities	46,997.70	
Laboratory research projects	1,426,864.20	
Administrative and general expense, less amounts transferred	115,586.07	
		1,915,499.01
Net operating loss		287,567.39
Other Income:		
Donations—Friends of Franklin	24,071.00	
Service fees from Bartol and Biochemical Foundations	14,868.57	
Appropriation—State of Pennsylvania	31,583.33	
Income from trust funds (including interest below from The Institute)	70,309.90	
		140,832.80
		146,734.59
Other Charges:		
Friends of Franklin	3,967.01	
National Franklin Committee	2,443.29	
Cafeteria expense (net)	4,763.94	
Interest	4,132.42	
Bad debts	211.33	
		15,517.99
Net deficit for the year		$ 162,252.58

The operations for the year, after including in costs a charge for depreciation of buildings and equipment amounting to $139,137, resulted in a deficit, as indicated, of $162,253, or $23,116 without such depreciation. Compared with a surplus of $86,087 for the year 1946, this deficit of $23,116 reflects the further restoration of activities suspended during the war, the reduction in government overhead allowances on research projects since the war, and increased costs in general operations. The budget for the current year indicates a deficit of $153,000 after depreciation of $173,000.

The group of about 250 individuals and companies comprising the Friends of Franklin has continued its generous support, contributing as indicated above the sum of $24,071 to the funds of The Institute during the year. Both the moral and material help of this important group is of such inestimable value that we should like to see it grow in numbers; and its financial assistance is of such aid to The Institute and its work with the community that we hope its contributions may even be increased this coming year.

The financial statements above bring into clear light the unfortunate fact that the crying need of The Institute now, just as before the war, is for largely increased unrestricted endowment to enable it to carry on the work to which it committed itself when its new building was erected in 1933. We are not unique in this respect; it is well known that scores and hundreds of similar institutions throughout the country, each serving the community in its own particular field, must have more income to meet rising costs and the expanding demands on their facilities or else restrict the services they are performing. We are hoping that a formal campaign can be started in the near future for this purpose. Even before its inauguration, however, perhaps there are those who have sufficient belief in our work to step forward and start the ball rolling. There would then be no doubt of The Institute's ability to continue its ramified scientific activities, so much a part of this present day and age. It would give renewed energy to the staff who have so well served us this past year as in earlier years and to whom the Board can be nothing but grateful.

Surely the 125 years of service which The Franklin Institute has rendered to this local community of Philadelphia and to the state and country at large in the "promotion of the mechanic arts" and in spreading the teachings of Benjamin Franklin—its patron saint and the country's great practical philosopher—would seem to merit support. Surely the early vision of our founders will be supported by the present generation in carrying forward the work which they so well began.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, June 9, 1948.)

HALL OF THE COMMITTEE,
PHILADELPHIA, JUNE 9, 1948.

DR. JULIAN W. HILL in the Chair.

The following report was presented for final action:

No. 3160: Development of Phospho-Asbestos.

This report recommended the award of an Edward Longstreth Medal each to Nicholas F. Arone, of Philadelphia, Pennsylvania, and Edwin H. Brink, of Laurel, Mississippi, "In consideration of their persistent search and ingenuity, resulting in the discovery of Phospho-Asbestos and in the chemical and productional development of this uniquely useful product."

JOHN FRAZER,
Secretary to Committee.

NEW MEMBERS OF THE FRANKLIN INSTITUTE ELECTED DECEMBER 1, 1947 TO JUNE 1, 1948.

NON-RESIDENT LIFE MEMBER.

Harry Sidney Newcomer, M.D.

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Mr. Bert W. Conn
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Mr. Leroy E. Zabel '42

LIBRARY NOTES.

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print 9×14 inches is thirty-five cents.

The Library and reading room are open on Mondays, Tuesdays, Wednesdays and Fridays from 9 A.M. until 5 P.M., Thursdays from 2 P.M. until 10 P.M., and Saturdays from 9 A.M. until 12 noon.

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Pulse Generators, edited by G. N. Glasoe and J. V. Lebacaz. 741 pages, 16 × 23 cm., tables, drawings and illustrations. New York, McGraw-Hill Book Co., Inc., 1948. Price, $8.00.

Supercharging the Internal Combustion Engine, by E. T. Vincent. 315 pages, 16 × 23 cm., plates, tables, drawings and illustrations. New York, McGraw-Hill Book Co., Inc., 1948. Price, $5.00.

Fatty Acids and Their Derivatives, by A. W. Ralston. 986 pages, 14 × 22 cm., tables and drawings. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd.; 1948. Price, $10.00.

The Modern Metallurgy of Alloys, by R. H. Harrington. 209 pages, 14 × 22 cm., plates, tables and drawings. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd.; 1948. Price, $3.50.

Dairy Bacteriology, by Bernard W. Hammer. Third edition, 593 pages, 15 × 23 cm., illustrations. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd.; 1948. Price, $6.00.

Physics of Metals and Alloys, by W. Boas. 193 pages, 16 × 25 cm., plates, tables, drawings and illustrations. New York, John Wiley & Sons, Inc., 1947. Price, $3.50.

Journal of the Society of Motion Picture Engineers, Index 1936–1945. 156 pages, 15 × 23 cm. New York, Society of Motion Picture Engineers, 1948.

Animal Breeding, by Laurence M. Winters. Fourth edition, 404 pages, 15 × 23 cm., tables, drawings and illustrations. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd.; 1948. Price, $4.50.

Eruptive Rocks, by S. James Shand. Third edition, 488 pages, 14 × 22 cm., drawings, illustrations and plates. New York, John Wiley & Sons, Inc.; London, Thomas Murby & Co.; 1947. Price, $7.50.

Fundamentals of Soil Mechanics, by Donald W. Taylor. 700 pages, 14 × 22 cm., tables, drawings and illustrations. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd.; 1948. Price, $6.00.

Quantitative Analysis, by Willis Conway Pierce and Edward Lauth Haenisch. Third edition, 520 pages, 15 × 23 cm., tables, plates and drawings. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd.; 1948. Price, $3.75.

Petroleum Production, by Park J. Jones. Volume 4, 238 pages, 15 × 23 cm., tables and drawings. New York, Reinhold Publishing Corp., 1948. Price, $5.00.

Encyclopedia of Chemical Reactions, by C. A. Jacobson. Volume 2, 917 pages, 16 × 23 cm. New York, Reinhold Publishing Corp., 1948. Price, $12.00.

Two-Dimensional Fields in Electrical Engineering, by L. V. Bewley. 204 pages, 16 × 24 cm., drawings and illustrations. New York, The Macmillan Co., 1948. Price, $5.50.

Aircraft Engines, by Colonel Rollen H. Drake. 348 pages, 16 × 24 cm., drawings and illustrations. New York, The Macmillan Co., 1948. Price, $5.90.

Chymia, edited by Tenney L. Davis. 190 pages, 16 × 24 cm., portraits and plates. Philadelphia, University of Pennsylvania Press, 1948. Price, $3.50.

Tables of Bessel Functions of Fractional Order, prepared by The Computation Laboratory of the National Applied Mathematics Laboratories, National Bureau of Standards. 413 pages, 20 × 27 cm., tables. New York, Columbia University Press, 1948. Price, $7.50.

Microwave Magnetrons, edited by George B. Collins. First edition, 806 pages, 15 × 23 cm., tables, drawings and illustrations. New York, McGraw-Hill Book Co., Inc., 1948. Price, $9.00.

BOOK REVIEWS.

DIE DISSERTATIONEN DER EIDGENÖSSISCHEN TECHNISCHEN HOCHSCULE, 1909–1946, EINE SYSTEMATISCHE BIBLIOGRAPHIE, by W. Mikulaschek. 142 pages, 15 × 21 cm. Zürich, AG. Gebr. Leemann & Co., 1948. Price, 10 Fr.

Representative of the useful bibliographical works published by many universities and other higher institutions of learning are lists of dissertations. The present volume is such a list and includes all the dissertations presented at the Eidgenössische Technische Hochschule from the first in 1909 to the end of 1946.

The dissertations have been arranged in a classified order, an outline of which is given. An alphabetical index to the outline is also included. Under each subject the entries are arranged alphabetically by author and include further the titles of the dissertation, the number of pages, place, printer, and date. Of the 1458 dissertations listed, 697 are in the field of chemistry. The remainder are divided among the various other branches of science and technology.

As the first volume of a new series "Schriftenreihe der Bibliothek der Eidgenössischen Technischen Hochschule," this volume offers an auspicious beginning.

G. E. PETTENGILL.

AMERICAN WOOL HANDBOOK, by Werner von Bergen and Herbert R. Mauersberger. Second edition, 1055 pages, illustrations, 13 × 19 cm. New York, Textile Book Publishers, Inc., 1948. Price, $8.00.

Originally published in 1938, this *Handbook* now appears in a revised and enlarged edition. The authors, both experienced in textile work, have been aided by twenty specialists in various phases of the wool industry.

The text covers the complete subject of wool from sheep raising to the finishing of the cloth. New material has been added in several sections, particularly on the chemical properties of wool, worsted yarn manufacture and the testing of wool. The many illustrations and a comprehensive bibliography will prove useful. With the extensive changes in this edition, this work remains an essential and up-to-date handbook for those interested in wool.

G. E. PETTENGILL.

WHAT ELECTRONICS DOES, by Vin Zeluff and John Markus. 306 pages, illustrations, 14 × 20 cm. New York, McGraw-Hill Book Co., Inc., 1948. Price, $3.00.

Electronics has become a common word since it was first chosen as the title of a periodical in 1930. The applications of electronics have multiplied to such an extent that the present book contains a selection of over four hundred examples.

The text is divided into nineteen chapters which present the subject from various viewpoints. Different types of electronic phenomena are presented in the first five chapters—

electrostatics, dielectric heating, induction heating, ultrasonics, and electronic viewers and phototubes. Then follow chapters on the use of electronics in particular media—in the air, on water, on land and underground. Specific functions that electronics may perform are also considered, such as inspection, production control, measuring, and counting.

The many uses of electronics range from those with which the average individual may come in contact, such as traffic controls, diathermy equipment, or safety devices on machinery, to the unusual application seen only by a few—a device for tracking schools of fish. Directly or indirectly nearly all the uses detailed in this book contribute in some way to increased efficiency or heightened production. Electronics has also made possible the accomplishment of many tasks hitherto thought impossible.

Written in a readable style with many illustrations, this book will be of interest to those who wish to learn about the wonders of electronics. Read carefully, it may suggest applications of electronics suitable to the reader's own business.

G. E. PETTENGILL.

VACUUM TUBES, by Karl R. Spangenberg. 860 pages, illustrations, 16 × 23 cm. New York, McGraw-Hill Book Co., Inc., 1948. Price, $7.50.

In the United States the number of vacuum tubes in use is several times its population, and comprises nearly half of the world's total. Thus, a textbook dealing with vacuum tubes only would seem highly appropriate.

In his book Dr. Spangenberg is concerned with the determination of vacuum tube characteristics in terms of the electron action within the tube. The development of the physical laws involved is indicated, after which emphasis is placed upon their description and utilization. Attention is centered on the internal factors which contribute to the operating characteristics of tubes over a broad range of types.

No attempt has been made to describe circuits and tube application, except in the case of ultra-high frequencies where the tube cannot be separated from the circuit.

More recent advances are comprehensively covered. A number of items hitherto unpublished in book form are also included. These include space charge flow, noise, specific characteristics of triodes, tetrodes, pentodes, etc.

H. N. MICHAEL.

VACUUM-TUBE CIRCUITS, by Lawrence Baker Arguimbau. 668 pages, illustrations, 14 × 22 cm. New York, John Wiley & Sons, Inc., 1948. Price, $6.00.

The material in this textbook, although often referring to matters of current interest, emphasizes general methods by which engineering problems can be attacked. Frequency modulation, basic material on transient response and generation of microwaves are particularly thoroughly covered.

Although the emphasis has been placed on physical concepts and ideas rather than on discussion of actual circuits, the ideas have been applied to specific numerical examples.

The book is written, in the main, for those who have a background in physics of the vacuum tube. Nevertheless much of this material has been summarized in the initial chapters and, besides, there are adequate references to the basic electronics needed for the pursuit of this study.

The sound expository treatment of the material and the frequent illustrations and problems present a well-knit and comprehensive text which recommends itself to the student specializing in this field.

H. N. MICHAEL.

POWER SYSTEM STABILITY, by Edward Wilson Kimbark. Volume 1, 355 pages, illustrations, 14 × 22 cm. New York, John Wiley & Sons, Inc., 1948. Price, $6.00.

This first volume of a three-volume work stresses transient rather than steady-state stability. Intended for the use of power-system engineers and graduate students, it covers the principal factors affecting stability, the ordinary simplified methods of making stability calculations, and illustrations of the application of these methods to actual power systems.

The related topics of a-c. calculating boards, fault studies, circuit breakers, protective relaying, synchronous-machine theory, exciters and voltage regulators, etc., are brought out clearly in the discussion of power-system stability, and thus increase the referential value of the book.

H. N. MICHAEL.

ELEMENTARY THERMODYNAMICS, by Virgil Moring Faires. Revised edition, 268 pages, illustrations, 16 × 24 cm. New York, The Macmillan Co., 1948. Price, $4.40.

The revised edition of this book presents textual material for short courses in thermodynamics. However, its brevity does not imply that the discussions within it are shortened. To the contrary, those topics that are presented are fully discussed. In words of the author, "Completeness in treatment of topics should not be sacrificed in order to include a wide range of material that would be appropriate for a course designed to be full in scope."

Many small changes have been made in this edition and a discussion on the theory of the gas turbine has been added. Most of the problems have been replaced or revised.

Specifically, the thirteen chapters of the book deal with general energy equation, characteristic and energy equations of a perfect gas, reversible nonflow processes of gases, Carnot and Ericsson cycles, cycles for internal combustion engines, the compression and expansion of air. There are three chapters on liquids and vapors, and also chapters on refrigeration, flow in nozzles, and on mixtures.

To most of the chapters are appended selected references and there is also a list of general references on thermodynamics.

H. N. MICHAEL.

TECHNIQUES IN EXPERIMENTAL ELECTRONICS, by C. H. Bachman. 252 pages, illustrations, 14 × 22 cm. New York, John Wiley & Sons, Inc., 1948. Price, $3.50.

Electronics, as discussed in this book, is defined as "that brand of science and technology which relates to the conduction of electricity through gases or in vacuo."

Starting with the description of the necessary apparatus, the book proceeds to the active production and measurement of vacua, instructs in the glass blowing fundamentals such as tubulation, glass seals, preparation of electrodes, etc., and also discusses the sources, control, and utilization of charged particles. There is also a chapter on the assembly and processing of electronic devices.

The author covers the basic techniques employed in electronics research and his book should prove valuable to physicists, electrical engineers, and others about to tackle research in this field.

H. N. MICHAEL.

FREQUENCY MODULATION, Vol. I, collected reprints by R. C. A. Engineers. 515 pages, illustrations, nomograms and charts, 14 × 23 cm. Princeton, *R. C. A. Review*, 1948. Price, $2.50.

In 1940 the R. C. A. Institutes introduced the plan of reprinting in a single volume the leading papers presented by its staff of engineers on such subjects as U. H. F. radio, facsimile and television. *Frequency Modulation*, Vol. I follows that pattern by reprinting 24 outstanding papers on general topics, transmission and reception, and miscellaneous FM subjects from the *Proceedings of the I. R. E.*, *Electronics*, *FM*, and *R. C. A. Review*. In addition, there are 21 summaries and abstracts which provide the necessary background material in the fields that lie within or near the scope of frequency modulation broadcasting. A bibliography of all the papers and articles on FM by R. C. A. engineers is given in the back of the volume, according to date.

Generally the review editors have made what appear to be rather good choices from quite an extensive selection. Some readers and engineers may, however, find the reprinting of the so-called "characteristic" series by Crosby to be out of date; while including such excellent articles as "The Input Impedance of Pentodes" by F. Mural which is not commonly available is highly commendable.

O. P. FERRELL.

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NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

A Method of Ultraviolet Photomicrography.—J. O. Ely and M. H. Ross. Photomicrographs of unstained cells and tissue sections made with ultraviolet light near 2600 A wave length, because of selective absorption of the light, reveal the location of purine and pyrimidine nucleotides and nucleic acids. Absorption of ultraviolet light by these compounds makes possible a comparison of the amounts in different tissues or in the same tissue under different circumstances, and with refined technic makes possible quantitative determinations of nucleic acids and other substances in cells.

A quartz optical system microscope, described in 1904 by Köhler and von Rohr of the Zeiss Optical Co. staff, which had attachments for photomicrography, has been employed by many investigators—Cas-

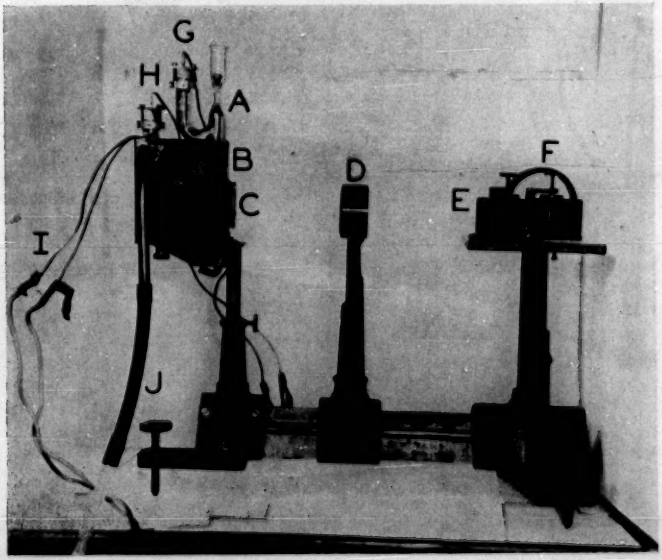

Fig. 1. Photograph of lamp-monochromator assembly. (*A*) Quartz-mercury lamp; (*B*) water-tight metal box holder for lamp with water inlet and outlet and quartz window (*C*); (*D*) collimator lens of quartz; (*E*) monochromator prisms of quartz; (*F*) collecting lens of quartz; (*G*) positive electrode; (*H*) negative electrode; (*I*) lead wires to heater; (*J*) water outlet.

persson and Schultz; Wyckoff; Lucas; Allen, Franklin and McDonald; Cole and Sutton; Ris and Pollister; Lavin; Mitchell; Bromburg; Loofbourow; and others. The difficulties of operation and the uncertainty

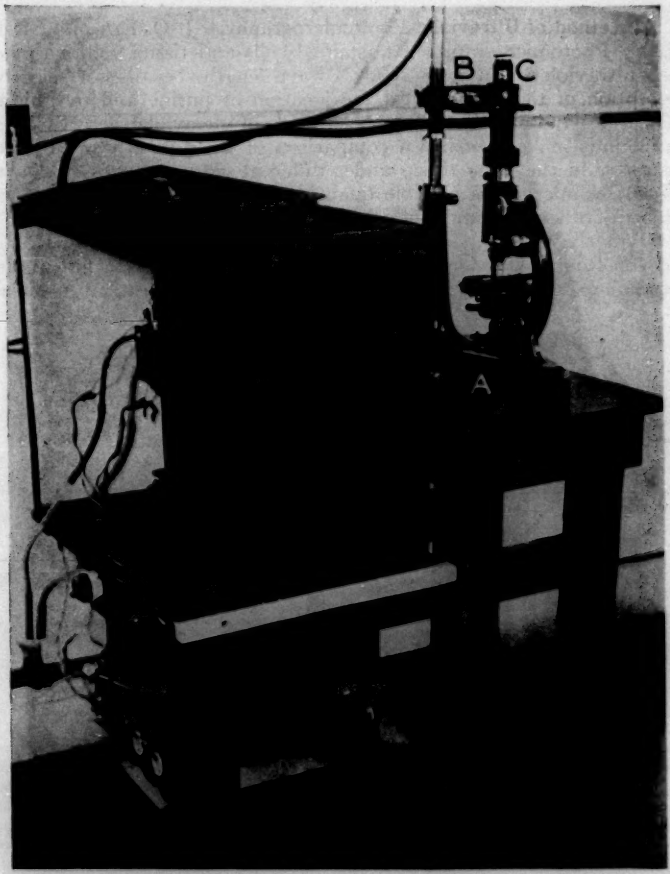

FIG. 2. Ultraviolet light photomicrograph apparatus. (*A*) Hole in base of stand through which monochromatic light passes to and is reflected upward by a totally reflecting prism in the optical axis of the microscope; (*B*) Leica camera in position for focussing; (*C*) magnifier used to aid in focussing.

of obtaining good quality photomicrographs with this apparatus were great.

The improved apparatus described here utilizes the Zeiss Optical Co. quartz microscope and monochromator. The various pieces of apparatus and their location in the assembly are shown in Figs. 1 and

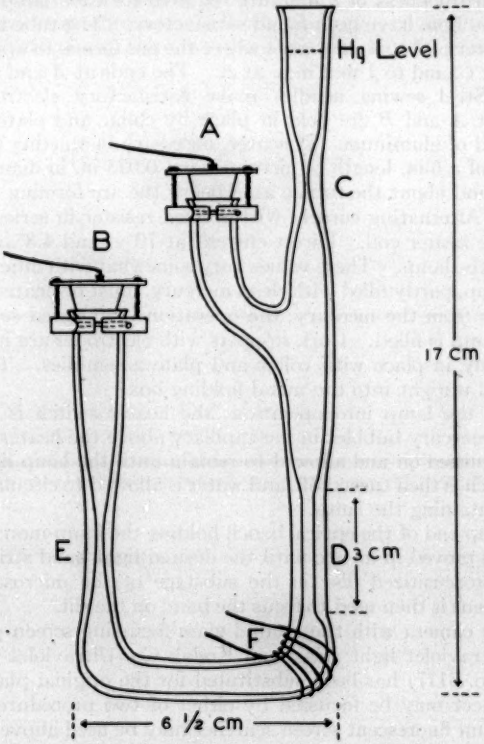

FIG. 3. Diagram of quartz-mercury lamp.

2. The essential changes from the original apparatus are substitution of a quartz-mercury lamp for the original cadmium electrodes and a 35-mm. camera for the original plate camera.

A circular disc of metal 33 mm. in diameter and 1 mm. thick with a slit 1 mm. wide and 20 mm. long across the center is placed in the substage of the condenser. The bottom surface of the disc is photo-

sensitized with Conti-Glo Pearl White Lacquer enamel 604, Continental Lithograph Co., Cleveland, Ohio.

The lamp is a modification of, and differs only slightly from the one described by A. J. Allen (*Science*, **83**: 336, 1936). A schematic diagram of the lamp is shown in Fig. 3. Approximately 15 in. of quartz tubing with a wall thickness of 2 mm. are required for each lamp. Tubes of 8 to 12-mm. bore have been found satisfactory. The tube is drawn out to a diameter of 3 to 4 mm. at *D* where the arc forms, to approximately 0.5 mm. at *C*, and to 1 to 2 mm. at *E*. The ends at *A* and *B* are flared slightly. Steel sewing needles make satisfactory electrodes. Cork stoppers at *A* and *B* are held in place by collar and plate assemblies constructed of aluminum. A heater, necessary in starting the lamp, is composed of a 6-in. length of nicrome wire, 0.025 in. in diameter. The wire is wound about the tubing at *F* below the arc forming area on the diagram. Alternating current with a fixed resister in series is used to operate the heater coil. Direct current at 70 v. and 4.8 amp. is used to operate the lamp. These values vary somewhat with different lamps.

The lamp, partly filled with clean mercury, must be heated to remove air bubbles from the mercury; the operation is repeated several times until the lamp is filled. Cork stoppers with electrodes are inserted and held securely in place with collar and plate assemblies. The lamp is then placed upright into the metal holding box.

To put the lamp into operation, the heater switch is turned on. When the mercury bubbles in the capillary above the heater, the direct current is turned on and allowed to remain until the lamp lights. The heater switch is then turned off, and water is allowed to circulate through the box containing the lamp.

The lamp end of the optical bench holding the lamp-monochromator assembly is moved in an arc until the desired light band strikes the slit of the photosensitized disc in the substage of the microscope. The collimator lens is then used to focus the band on the slit.

A Leica camera with the ground glass focussing screen photosensitized to ultraviolet light (Eastman Kodak Co. Ultraviolet Sensitizing Solution No. 3177) has been substituted for the original plate camera.

The object may be focussed by either of two procedures: (*a*) The Zeiss uranium fluorescent screen searcher may be used above the ocular of the microscope. The object is easily focussed, especially when the strong mercury band 2654 Å or 2536 Å is used. The camera is then put into place. With the aid of a small hand magnifier, the image is focussed on the photosensitized focussing screen of the camera. (*b*) The image may be focussed directly on the focussing screen of the camera without preliminary use of the uranium screen searcher.

Twelve microscopic fields can be photographed, three exposures per field, on one roll of 35-mm. film, in a short time. Almost invariably a

well focussed negative is obtained from three exposures at slightly different settings of the fine adjustment of the microscope.

Summary.

A specially constructed quartz-mercury lamp and a 35-mm. camera have been adapted for use with a Zeiss Optical Co. quartz optical system microscope and monochromator. With this improved apparatus ultraviolet light photomicrography may be easily and rapidly accomplished.

CURRENT TOPICS.

New Technique Facilitates Brazing Stainless Steel Parts.—The coming era of jet engines and rockets is being accelerated by the development of a new brazing technique which makes possible the joining of precision, high-temperature, stainless-steel parts.

Furnace brazing, the uniting of several metal parts by melting a metal such as copper into the joints, has been extremely difficult in the case of the heat-resistant alloys containing chromium necessary in the construction of jet engines and rockets. Or, when flux, a chemical for preventing oxidation, was used, the cost of removing flux deposits afterwards has been excessive and time-consuming.

The new process succeeds with tricky stainless-steels by brazing them in a hydrogen atmosphere more pure than any previously used. When moisture or oxygen is present in a furnace atmosphere without flux, the chromium will oxidize.

The parts to be brazed are sealed in a box, which is then filled with pure hydrogen. As in regular furnace brazing operations, copper is placed adjacent to the joints to be bonded, so that when molten it will creep into the joints. The sealed box is introduced into the heating chamber of an electric furnace for 20 min. to an hour. It is then allowed to cool. Before removing the box from the cooling chamber, the hydrogen, which is explosive when mixed with air, is exhausted and replaced by nitrogen, which is not.

The furnace brazing of assemblies by this new technique is sometimes used as an alternative to making parts by the more common methods of forging, casting, machining from solid stock, or even other fabricating methods such as torch brazing. Machining time and waste metals are often reduced in such instances. Intricate assemblies sometimes can be fabricated which otherwise could not be made any other way and still obtain the quality and results needed. The perfectly clean, bright surfaces, after furnace brazing, are a particular advantage.

R. H. O.

Germ-Less Air (Marjorie Fisher, *Science Illustrated*, May, 1948).—A new machine called a glycol vaporizer may revolutionize the long fight against air-borne germs. Respiratory diseases, caused by these germs, annually cost the United States 220,000,000 days and $1,500,000,000. The battle against these costs has progressed through the ventilation, dust-removal, and ultraviolet ray stages, all of which have their drawbacks. In 1941, Dr. Ostwald Robertson, searching for a good air germicide, discovered that triethylene glycol was practical, since it is odorless, fireproof, and hygroscopic. When heated, triethylene glycol gives off a vapor which surrounds the germs in the air and kills most of them. One part of glycol vapor in 400-million parts of air can clear that air of almost everything harmful, including influenza virus, pneumococcus, and streptococcus. The vaporizer was designed by Frederick Schmitz and

has been used in pharmaceutical plants, hospitals, theaters, and the White House. Industrial plants may purchase a large 45-lb. machine for about $385 for use with air conditioning systems. A small 10-lb. machine suitable for one room—office, home, or hospital—costs about $50, with operating expense of about $1.50 a month.

Soil Organisms in Vital Contests.—What scientists bring to light on the life that teems about the roots of crop plants indicates complexes of great variety based on physical and chemical conditions, on fungi, bacteria, insects, nematodes, to mention a few.

A recent study of factors influencing the growth of the fungus that causes foot rot of wheat, the so-called "take-all" disease, emphasizes those complicated interrelations which slow down the solution of many crop problems. This requires that scientists of different kinds look at them from different directions.

The scientists—in this case working in Kansas—found that a number of common soil fungi are antagonistic in various ways to the one that causes the "take-all;" while others at the same time produced stimulants that made the "take-all" take more. Some were found to be direct parasites on wheat roots, others produced substances disturbing to growth of the grain. But some of the beneficial ones were only fair weather friends, shifting their roles with conditions, a disturbing situation suggesting a kind of biological treason.

In view of this very mixed situation, say the experimenters, it may be that adding certain amendments to a field will enable some common soil fungi to produce byproducts (hormone-like substances or what not, biotics or antibiotics) that work either for or against what the farmer is trying to do.

After unearthing these difficulties and possible advantages in the biological and other complexes of the root zone, the scientists say there is some hope of ultimate practical use of such knowledge. Although results as yet are not very consistent, and tests have been on a small scale, sometimes the severity of "take-all" has been reduced by increasing the population of certain fungi.

R. H. O.

Elastic Truths Measure Stretch in Fabrics.—Familiar as knit fabrics are, in such things as sweaters, hose, close-fitting underwear, and gloves, the textile and clothing industry has had relatively little scientific information to go on in producing best materials for elasticity—the stretch and recovery or come-back—that makes possible a close yet comfortable fit.

Pioneering in some lines of this research, textile specialists have had to start by devising their own apparatus and procedure to measure elastic recovery of yarns and fabrics under various stresses and strains. Tests thus far completed have yielded technical data on the stretch and come-back of yarns and plain knit fabrics.

Elastic come-back of fabrics cannot be predicted by knowing that of yarns. This is one point thus far learned. Nylon yarn, for example, is far more elastic, than yarn of wool or silk. But when the same yarns have been made into plain knit fabrics, the wool or silk fabric is more elastic than the nylon fabric, say Dr. Hazel M. Fletcher and Pearl A. Gilmore, who have been conducting these tests in the Bureau of Human Nutrition and Home Economics.

Yarns of cotton, linen, wool, silk, nylon, and the three types of rayon have been compared, and also 19 plain knit fabrics, some loosely knit with 40 courses to the inch, some tightly knit with 64 courses.

The two types of fabrics, loosely and tightly knit, point up another problem in elasticity, the research scientists have found. A yarn that has greater elastic recovery when knit into fabric of a certain number of courses may have much less in other fabrics. Plain knit fabrics of wool have more elastic recovery when loosely knit. Those of nylon, silk, and rayon have more recovery when tightly knit.

In further research, Dr. Fletcher and Miss Gilmore are measuring elastic recovery of other constructions of knitwear, such as ribbed fabrics, and plated fabrics made of two layers of different kinds of yarns.

R. H. O.

Manufacturing Advances in Wartime Germany (John L. Kent, *Scientific American*, April, 1948).—American manufacturers can improve their products, add profitable lines and even start new businesses by making use of technical information on German processes and equipment which can be obtained from the Office of Technical Services, Department of Commerce, in Washington. Thousands of these reports, prepared by industrial intelligence "detectives" during surveys of German industry, are being sold—some for less than a dollar. They include descriptions of processes and equipment, formulas, plant layout and other technical data, selected especially by the investigators as being useful to American industry. Examples of the sort of information available are: a process to extrude cold steel, which greatly increases production in sheet metal stamping; salt-bath heat-treatment methods for case hardening, decarbonizing, neutral surface treatments, and for quenching; description of a high-speed trip magnet to afford proper electrical contact in resistance welding; the development of economical and efficient brushes and commutators from powdered copper and iron.

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Dehydrofreezing.—Dehydrofreezing is the name of a new process of fruit and vegetable preservation that has been developed in California.

This new method combines the advantages of dehydration with those of quick freezing. It carries the product through the first cycle of dehydration, which removes a considerable amount of the weighty moisture, and then freezes it. Vitamins and flavor are virtually undamaged; so the treated product not only retains the fresh quality, but in some instances its original shape also.

This new method seems to be better than either dehydration or freezing, partly because there is less destruction of tissues by the larger ice crystals that tend to be formed when a greater amount of water is present. The chief advantage of this process is a considerable saving in weight and bulk, which in turn creates a saving all down the line, including packaging materials, storage space, and transportation facilities.

R. H. O.